Research on Complex Multi-pollutants Control Technology in a Large-scale Coal-fired Power Plant

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Abstract: The combined Selective-Catalyst-Reduction and Multi-Circulating-Fluid-Bed (SCR-MCFB) technology was investigated on a 300 MW boiler in a coal-fired power plant. The influence of this combined technology on the efficiency of dust collection, desulphurization, and denitrification, especially the interaction and the match of each system, was studied in order to improve the performance of the flue gas cleaning systems. Meanwhile, the ability on removing mercury of this combined system was studied with Ontario-Hydro (OH) method. The experimental results showed that the combined SCR-MCFB technology can remove not only SO_2, NO_x and dust but also mercury in the flue gas with high efficiency.

Keywords: ESP, SCR, MCFB, Mercury Removal

1 INTRODUCTION

The air pollutants of coal-fired power plant include dust, SO_2, NO_x, and also various trace heavy metals , such as mercury et al. As a bio-accumulative substances , mercury is very harmful to human health. Because the coal consumption of coal-fired power plant in China reaches more than one billion tons every year, the emissions of SO_2, NO_x and mercury becomes a very serious problem. In recent years, as the national standards on environmental protection being stricter and stricter, the combined flue gas cleaning systems including desulphurization, denitrification, and dedusting equipments et al., began to be installed at coal-fired power plants etc. These equipments played an important role on controlling the emissions of multi-pollutants. The research [1-4] about the ability of equipment on removing SO_2, NO_x and mercury in flue gas has been carried on extensively. Yang et al. [5] studies the semi-dry desulphurization device of deviating from SO_2, while the removal ability and mechanism of heavy metal mercury. Chen et al. [6] investigated the ability of SCR/ESP/seawater technology on removing mercury and the morphology change of mercury was also studied. In this paper, the efficiency of desulphurization, denitrification and dust collection were measured on a 300 MW boiler in a coal-fired power plant which adopted combined SCR-MCFB technology. And the mercury emission characteristics of this system are studied with the OH method as well. The research was expected to play a fundamental role on the effectively control of mercury by existed equipments of desulphurization, denitrification and dust collection.

2 SYSTEM AND MERCURY SAMPLING METHOD

2.1 Desulphurization and Denitrification System

The complex multi-pollutants control technology in coal-fired power plants adopted in this paper is shown in Fig. 1. The detailed principle is described as follows. After passing through the coal economizer , the flue gas flows into SCR. By injecting NH_3 into SCR, the NO_x is removed under the catalytic action. Then the flue gas flows through the air preheater and the first ESP into MCFB desulphurization absorber, passing the absorber bottom where Venturi tubes are installed. Calcium-based sorbent and atomized water is sprayed into the desulphurization absorber, in order to accelerate the reaction between SO_2 and sorbent. Meanwhile, the dusts containing unreacted sorbent collected by the bag filter are circulated into the absorber to continually react with the SO_2. So the sorbent is used with high utilization percent. A vortex generator and special top structure of absorber are adopted in order to strengthen the shearing and rub among the absorbent particles, flying dust particles and smoke. Both the internal circulation of material and the residence time in absorber are increased by this special design. Thus the removing efficiency is improved. The flue gas with high concentration of dusts emitted from the absorber then flows into a fabric filter (FF) with a collection efficiency of about 99.99%. Finally, the clean flue gas is discharged into atmosphere through the flue, induced draft fan and chimney.

The system configuration and the distribution of sampling points are shown in Fig. 2. Various components of flue gas are measured by online analyzer, and the concentration of mercury is measured with Ontario method based isokinetic sampling.

2.2 OH Method

The Ontario-Hydro method recommended by Environmental Protection Agency (EPA) is adopted for mercury sampling in the flue gas.

This method is a standard test method to analyze elemental mercury, oxidized mercury, particle-bound mercury and total mercury of stationary sources. The sampling procedure of OH method is shown in Fig. 2. The flue gas is sampled by isokinetic method and the dust contained in flue gas is removed through the glass fiber filter paper. There is a heating belt twisted between the stainless steel sampling gun and absorption bottles to keep the gas temperature be about 120 □. The flue gas passes through eight absorption bottles subsequently. Both the divalent mercury and zero-valent mercury are absorbed. The solid sample is saved by self-sealing polyethylene reagent bags. And the solution sample is saved by borosilicate bottles.

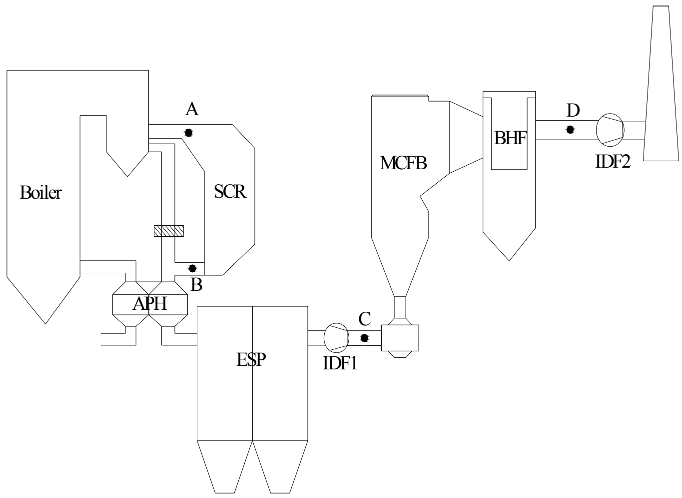

Fig. 1 The combined process to remove multi-pollutants in coal-fired power plant

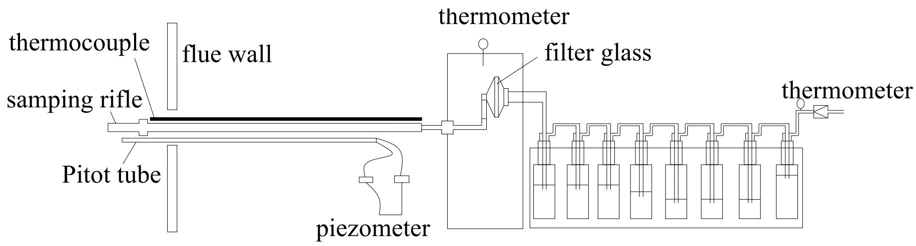

Fig. 2 Sampling process of mercury in flue gas with OH method

The absorption solution sample is then recovered and digested according to OH method (ASTM D6784). The digestion device used is the EYHOS E type microwave extraction/digestion labstation made in Italy by Milestone Company. The concentration of mercury in digestion solution is measured using Cold Vapor Atomic Fluorescence Spectrometry (CVAFS) method. The sampling of dust is completed by LPI and flue dust sampling instrument. The entire test procedure has been done three times to take the average value.

3 TEST RESULTS AND DISCUSSION

In order to understand the performance of combined flue gas cleaning system on removing multi-pollutants and the efficiency of removing various pollutants, the detailed investigation on the overall efficiency of denitrification, desulphurization and dust collection in this system were carried out, and the mercury removing efficiency of whole system was measured in some separate cases. Discussion on the test results is presented in following.

3.1 The Desulphurization Test Results

The desulphurization system is stable in operation after its start-up. The desulphurization efficiency has reached or exceeded the design value. The main operation parameters are shown in Table 1 under the load of 280 MW. The concentration of SO_2 and dust in discharged flue gas is lower than national standards. The average concentration of emitted dust is only 5.4 mg/Nm^3 within a long operation period.

3.2 The Denitrification Test Results

The denitrification system is stable in operation after its start-up. The denitrification efficiency has reached or exceeded the design value. The main operation parameters are shown in Table 2 under the load of 280 MW. The concentration of NO_x in the exhaust flue gas is lower than national standard.

3.3 Test Results of Mercury Removal

For the reliability of the test results, all the tests are carried on in the same condition. The operation parameters of the whole system are shown in Table 1. And the test results of elemental mercury, oxidized mercury, particle-bound mercury and total mercury in flue gas are presented in Table 3.

As can be seen from Table 3, the morphology of gaseous mercury changed greatly after SCR. With the influence of SCR, the concentration of elemental mercury decreased from 5.76 μg/m^3 to 0.95 μg/m^3, and its percentage in total mercury dropped to 6.75% from 39.7%. Meanwhile, the concentration of divalent mercury in flue gas rose to 10.8 μg/m^3 from 5.72 μg/m^3, and its percentage in total mercury rose to 76.8% from 39.4% in flue gas. This was mainly because that V_2O_5-WO_3/ TiO_2 contained in catalyst participated in the oxidation process of mercury. When passing through the surface activation center of catalyst, the elemental mercury in flue gas was oxidized into divalent mercury. So the proportion of elemental mercury in total mercury decreased and the proportion of divalent mercury increased.

It can be found from Table 3 that the concentration of total mercury decreased sharply after MCFB. It is reduced from 13.11 μg/m^3 to 1.54 μg/m^3.The removing efficiency of MCFB system on the elemental mercury reached 100%. And the efficiency was 90.9% for the divalent mercury and 43.8% for particle-bound mercury. Thus the total mercury removing efficiency of MCFB can reach 88.2%. From above results, the MCFB system can remove not only SO_2 from flue gas efficiently, but also mercury. So the multi-pollutants emissions of the coal-fired power plant can be controlled effectively.

Table 1 Operation parameters of desulphurization system (280 MW)

Item	Variable	Unit	Value
Original parameter of exhaust gas	Inlet volume	Nm^3/h	1010000
	Inlet temperature	℃	136
	Inlet concentration of O_2	%	5.4
	Inlet concentration of SO_2	mg/Nm^3	2623
Desulphurization system	Pressure drop in desulphurization absorber	kPa	1.07
	The tower top temperature	℃	75.6
	Water volume	t/h	33
	The ratio of Ca/S		1.3
Gas clear system	Bag filter pressure drop	kPa	1.84
	Outlet concentration of dust	mg/Nm^3	5.6
	Outlet temperature	℃	74.2
	Outlet concentration of O_2	%	5.72
	Outlet concentration of SO_2	mg/Nm^3	220
Power consumption	ESP power consumption	kWh	227.9
	Absorber and bag filter power consumption	kWh	385.5

Table 2 Operation parameters of denitrification system (280 MW)

Item	Unit	Data
Inlet volume	Nm^3/h	1010000
NH_3/ NO_x	Mol/mol	0.86
Inlet O_2	Vol%	2.35
Inlet NO_x	mg/Nm^3	403
Inlet temperature	□	352
Outlet NO_x	mg/Nm^3	56
Outlet temperature	□	335
Reactor pressure drop	Pa	440

Denitrification efficiency	%	86.1

Table 3 Mercury concentration in flue gas (280 MW)

Position	Oxidized mercury (μg/m^3)	Elemental mercury (μg/m^3)	Particle-bound mercury (μg/m^3)	Total mercury (μg/m^3)
Before SCR(A)	5.72	5.76	3.02	14.5
After SCR(B)	10.8	0.95	2.32	14.07
Before MCFB(C)	11.2	0.98	0.93	13.11
After MCFB(D)	1.02	0	0.52	1.54

4 CONCLUTIONS

Experiments have been done in a 300 MW boiler of a coal-fired power plant to investigate on the multi-pollutants removing ability of the combined SCR-MCFB technology. The test results showed that this combined flue gas cleaning technology can remove SO_2, NO_x, mercury, and dust in exhaust gas efficiently to control the emissions of coal-fired power plants.

The SCR system can remove NO_x in the flue gas efficiently. When the ratio of Ammonia to Nitrogen was 0.86, the denitrification efficiency can be more than 86%. The SCR system can also change the morphology of mercury in the flue gas and 83.5% elemental mercury was oxidized into divalent mercury.

The MCBF system can remove SO_2 and dust in the flue gas efficiently. When the ratio of calcium to sulphur was 1.3, the desulphurization efficiency was more than 91.6% and the concentration of dust in exhaust gas was only 5.4 mg/m^3. The MCFB system can also remove mercury in the flue gas efficiently and its total mercury removing efficiency can reach 88.2%.

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REFERENCES

1. Yang H. M., Pan W. P., Transformation of mercury speciation through the SCR system in Power plants, Journal of Environmental Sciences, 19(2007): 181-184.
2. Eswaran S., Stenger H. G., Understanding mercury conversion in selective catalystic reduction catalyst, Energy and Fuels, 19(2005): 2328-2334.
3. Zhao X. D., Xiang G. M., Yao Q., et al. Mechanism of dry FGD process and characters of circulating particles, Proceedings of CSEE, 26(2006): 70-76 (in Chinese).
4. Ghorishi S. B., Sedman C. B., Low concentration mercury sorption mechanisms and control by calcium-based sorbents: Application in coal-fired processes, Journal of the Air & Waste Management association, 48(1998): 1191-1198.
5. Yang L.G., Duan Y.F., et al., Investigation on depriving of mercury during novel integration semi-dry flue gas desulfurazation, Proceedings of CSEE, 28(2008): 66-71 (in Chinese).
6. Chen J. S., Yuan D. X., et al., Effect of flue gas cleaning devices on mercury emission from coal-fired boiler, Proceedings of CSEE, 28(2008): 72-76 (in Chinese).