Application of Semi-dry Flue Gas Desulfurization Technology in Circulating Fluidized Bed Boilers

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Abstract. The application of semi dry desulfurization technology in a circulating fluidized bed boiler is introduced in the paper. The principle and technical characteristics of semi dry desulfurization process are described in detail. The semi dry desulfurization process has certain reference value in the application of circulating fluidized bed boilers.

1. Introduction
The circulating fluidized bed boiler has the advantage of high efficiency, wide fuel adaptability, flexible load regulation, good environmental performance and so on [1]. It is considered to be a widely used clean combustion energy. It uses sulfur reinforcement agent to react with raw coal in the furnace, SO₂ is removed during combustion [2]. With the more and more stringent environment standards, the addition of limestone or other sulfur fixation agents in the CFB boiler furnace has been unable to meet the depressurization goal, the external desulfurization must be added. The need to increase the furnace desulfurization and circulating fluidized bed boiler equipped with flue gas desulfurization has a variety of options [3, 4]. In order to simplify, the in-furnace desulfurization can be canceled. Based on the pulverized coal furnace flue gas desulfurization experience, only the wet limestone desulfurization would be taken.

2. Project overview
A power plant in northern China has two 330MW coal-fired generating units. The boilers use sub-critical natural cycle once intermediate reheat circulating fluidized bed technology, and the fuel is coal gangue. In order to meet the emission standards, circulating fluidized bed boiler desulfurization in furnace is adopted, followed by circulating fluidizedbed semi-dry desulfurization process with flue gas after furnace.

The flue gas desulfurization process of coal-fired power plant boiler mainly includes dry desulfurization, semi-dry desulfurization and wet desulfurization. The wet desulfurization process of limestone gypsum has mature technology and high desulfurization efficiency, and it is widely used. By contrast, dry desulfurization industry desulfurization efficiency is low, as well as its desulfurization agent utilization rate, it is mainly used in circulating fluidized bed boiler; Semi-dry desulfurization has simple process, high desulfurization efficiency, small occupation of the burning process, no waste water discharge and other characteristics, which is suitable for circulating fluidized bed boiler desulfurization transformation.
3. Process introduction

Half dry desulfurization dust removal integration technology is applied in this project, the desulfurization process is mainly composed of an absorbent supply system, absorption tower, recirculation system, flue gas system, process water system, filter, fluidization, transmission system, electrical system and control system components including absorber using hydrated lime, calcium carbide slag, the main ingredients for the Ca (OH). At the same time, a digester would be set up.

The process flow chart is shown in Figure 1. In figure 1, 1 is the digester, 2 is the desulfurization absorption tower, 3 is the bag dust collector, 4 is the induced draft fan, 5 is the chimney, 6 is the ash storage.

![Figure 1. Circulating fluidized bed semi-dry desulfurization process flow chart.](image)

After selective non catalytic reduction of boiler denitration, the flue gas passes through the boiler tail heating surface, exchanges heat in tubular air preheater, (the main flue gas parameters are shown in table 1) then it enters the smoke acceleration zone from the bottom, under the action of 7venturi tubes, flue gas and solid materials formed circulating fluidized bed desulfurization tower body in mixed reaction zone. In the circulating fluidized bed, due to the action of the airflow, two phases, namely the gas and solid, produce intense turbulence and mixing full contact. In the venturi outlet expansion section, provided with a spray device, spray atomization cooling takes effect, they can also be formed as a liquid film on the surface of the absorbent, reacts with SO2 in flue gas totally. When the reaction is completed, the main component of the by-product is CaSO3 1/2 H2O, CaSO4 1/2 H2O and the absorbent Ca(OH)2 that is not fully reacted, and a small amount of impurities in the absorbent.

| Item                                      | Unit         | Desulfide dust island entrance (6%O2) |
|-------------------------------------------|--------------|---------------------------------------|
| Smoke volume (dry)                        | Nm³·h⁻¹      | 1179147                               |
| Smoke volume (wet)                        | Nm³·h⁻¹      | 1296191                               |
| Flue gas temperature at the inlet of desulfurization system | °C          | 150                                   |
| Carbon dioxide (dry base)                 | %            | 13.37                                 |
| Oxygen (dry group)                        | %            | 6.11                                  |
| Nitrogen (dry group)                      | %            | 80.49                                 |
| Water vapor (wet base)                    | %            | 8.59                                  |
| Sulfur dioxide (dry base)                 | mg·m⁻³       | 763                                   |
| HF concentration                          | mg·m⁻³       | 20                                    |
| HCl concentration                         | mg·m⁻³       | 30                                    |
After semi-dry desulfurization is discharged sideways from the top of the desulfurization absorption tower and enters the bag dust collector after desulfurization for gas-solid separation. The induced draft fan is used to discharge through the chimney to reach the standard before the gas is discharged. The dust collected by the cloth bag dust collector can enter the desulfurization tower for reaction through the desulfurization ash recirculation system. The biggest feature of the system is that it can efficiently complete the integration of desulfurization and dust removal. Using the desulfurized dust collector, the flue gas does not need to be removed in advance before entering the desulfurization absorption tower, and the purpose of achieving energy saving and efficiency improvement will be accomplished. The absorbent can remove the SO\(_2\) in most parts of the flue gas, as well as the HCl, HF acid gaseous pollutants. The reaction process of circulating fluidized bed desulfurization process is as follows:

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\begin{align*}
\text{Ca(OH)\textsubscript{2}} + \text{SO}_2 & \rightarrow \text{CaSO}_3 \cdot \frac{1}{2}\text{H}_2\text{O} + \frac{1}{2}\text{H}_2\text{O} \\
\text{Ca(OH)\textsubscript{2}} + \text{SO}_3 & \rightarrow \text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O} + \frac{1}{2}\text{H}_2\text{O} \\
\text{CaSO}_3 \cdot \frac{1}{2}\text{H}_2\text{O} + \frac{1}{2}\text{O}_2 & \rightarrow \text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O} \\
\text{Ca(OH)\textsubscript{2}} + \text{CO}_2 & \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} \\
2\text{Ca(OH)\textsubscript{2}} + 2\text{HCl} & \rightarrow \text{CaCl}_2 \cdot \text{Ca(OH)}\textsubscript{2} \cdot 2\text{H}_2\text{O} \\
\text{Ca(OH)\textsubscript{2}} + 2\text{HF} & \rightarrow \text{CaF}_2 + 2\text{H}_2\text{O}
\end{align*}
\]

4. **CFB semi-dry desulfurization process operation problems and solutions**

The most common problem of CFB semi-dry desulfurization process is the easily clogged desulfurization system while the unit load is low. At present, the main solutions are: first, to adjust the water injection desulfurization tower. Second, to control the amount of absorbent; third, to adjust the circulation amount of desulfurization ash; fourth, to adjust the flow of purification flue gas.

4.1. **Adjust the water injection of the desulfurization tower.**

By monitoring the temperature of flue gas at the outlet of the desulfurization absorption tower, the water injection of the desulfurization tower can be controlled and the temperature can be adjusted. Circulating fluidized bed semi-dry desulfurization process uses high-pressure atomization backflow spray gun device, the maximum output of the high-pressure water pump used is 1.2 times of the water consumption at full load. When the temperature changes, the adjustment of the spray water and temperature changes synchronously, and it can quickly adapt to the change of boiler load.

4.2. **Control the amount of absorbent**

Monitoring the desulfurization and dust removal system to control the amount of absorbent. Continuous on-line monitoring system for flue gas would be installed around the island of desulfurization and dust removal, the desulfurization efficiency can be got by testing the concentration of SO\(_2\) in flue gas at inlet and outlet of desulfurization tower as well as calculating the sulphur removal efficiency. Based on the above numbers and results, the theoretical addition of the desulfurizing tower can also be figured out, so as to adjusting the amount of absorbent added coarsely. Through the combination of coarse adjustment and fine adjustment, the amount of absorbent can be adjusted quickly, and accurately to adapt to the change of boiler load.

4.3. **Adjust the circulation amount of desulfurization ash**

By monitoring the pressure drop of the desulfurization absorber and the circulation amount of desulfurization ash, the Variation of boiler load can be satisfied. The boiler load Pressure detection points are installed at the inlet and outlet of the desulfurization absorption tower, so that the bed particle concentration in the desulfurization absorption tower can be calculated. When the boiler load is reduced, the flow rate through the desulfurization absorption tower and the load of SO\(_2\) would reduce. In order to stabilize the fluidized bed, the particle concentration in the desulfurization absorber must be decreased.
Therefore, the requirement of load reduction can be met by reducing the circulation amount of desulfurization ash.

4.4. Adjust the flow rate of purification flue gas
Setting up clean air compensation system as well as adjusting the flow of purification flue gas can meet the change of boiler load. The static pressure of desulfurization tower entrance flue is lower than desulfurization induced draft fan export, so no additional Suction fan is needed. Clean wind compensation system will be used to purify part of the smoke induced by draft fan at the downstream part. According to the load change, by adjusting the windshield and the net smoke flow that recycled to the desulfurization tower inlet flue, the venturi nozzle flue gas flow rate can be kept stable.

5. Operation effect of semi-dry desulfurization
Through real-time and manual monitoring of flue gas online monitoring system, the flue gas composition before and after desulfurization was analyzed. It was concluded that the flue gas composition reached the design requirements after desulfurization in circulating fluidized bed furnace and semi-dry circulating fluidized bed desulfurization and the emission index was in line with the latest Emission Standard of Air Pollutants in Thermal Power Plants. The sulfur dioxide emission concentration reduces from 793 mg/Nm to 36.15 mg/Nm. And the dust emission concentration is 3.51 mg/Nm after using the cloth bag dust collector. In other words, the operation has achieved good social benefits.

6. Conclusion
The semi-dry desulfurization process has been successfully applied in desulfurization upgrading and transformation. It has been running continuously and stably for 4 years. The effect of desulfurization and dust removal is remarkable, which can achieve safe and stable long term operation. Semi-dry desulfurization process has the characteristics of high desulfurization efficiency, less investment, and no desulfurization wastewater. It is suitable for desulfurization transformation of circulating fluidized bed boiler, as well as the renewal of the unit with narrow site and short construction period.

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