Influence of Mixed Sludge on the Operation of Coal-fired Unit Boiler

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Abstract. In this paper, the operation characteristics of a 480t/h ultra-high pressure pulverized coal fired boiler with municipal sludge were studied. The results show that: mixing sludge has a negative impact on the thermal efficiency of boiler operation, and with the decrease of boiler evaporation and the increase of sludge mixing ratio, the decline of boiler thermal efficiency increases, but mixing sludge can effectively reduce the emissions of nitrogen oxides and sulfur dioxide in the boiler. Through the optimization and adjustment test, it is found that the optimal oxygen content of the boiler is 3.61% when the proportion of sludge is 5%.

Keywords: Mixed sludge, Power Plant Boiler, Operation adjustment.

1. Introduction
How to effectively treat municipal sludge has become one of the major problems facing the rapid development of urbanization [1]. The moisture content of wet sludge in sewage treatment plant is generally more than 80%, the calorific value is about 0.1 ~ 3MJ/kg, and the calorific value of dried sludge is about 6 ~ 12MJ/kg. Comprehensive utilization of municipal sludge and industrial sludge by coal-fired units has become one of the important directions of sludge treatment at home and abroad [2]-[3]. Due to the characteristics of high moisture content, high ash content and low calorific value of municipal sludge, further study is needed on the effect of drying of municipal sludge by coal-fired units and co-firing on boiler combustion, coking, pollutant emission and unit economy. In this paper, a 480t/h power plant boiler was used to test the effect of sludge blending on boiler operation characteristics. Through the optimization test, the boiler operation oxygen suitable for sludge blending was found.

2. Equipment introduction and test method

2.1. Equipment introduction
The boiler tested is SG-480/13.7-M767 single drum natural circulation boiler, which adopts ball mill and storage type exhausted gas pulverized coal feeding system. Sludge comes from municipal sewage treatment plant with moisture content of about 85%. Flue gas is used as drying material. Part of flue gas is taken from the inlet of air preheater and part from the outlet of electrostatic precipitator. The tail
gas of dryer is sent to boiler exhaust system by induced draft fan through cyclone, and the separated solid particles are recycled.

Table 1 shows the composition analysis of coal and sludge.

| Item    | Mar (%) | Mad (%) | Aad (%) | Vad (%) | FCad (%) | Qar.net (MJ/kg) |
|---------|---------|---------|---------|---------|----------|-----------------|
| Sludge  | 87.48   | 10.25   | 22.19   | 60.25   | 7.31     | 0.25            |
| Coal    | 9.20    | 2.42    | 32.48   | 27.06   | 38.04    | 18.22           |

It can be seen from table 1 that compared with coal, the fixed carbon content of sludge is very low, and the volatile matter is twice that of coal. The received basis calorific value of sludge is very low, only 0.25 MJ/kg. After drying, the air dry basis calorific value is 16.3 MJ/kg.

2.2. Process of sludge blending in coal fired boiler

The sludge drying and mixed burning process of a power plant is shown in Figure 1.

![Fig. 1 Process of drying sludge and mixing sludge in coal fired boiler](image)

3. Results and analysis

3.1. Effect of mixing sludge on boiler efficiency and pollutant emission characteristics

The boiler efficiency and NOx emission characteristics at furnace outlet were tested under the condition of 5% heat blending ratio and other parameters maintained in the normal operation mode of operators. The boiler evaporation capacity was 450t/h, 410t/h, 350t/h and 210t/h. The economic changes and emission characteristics of the boiler with and without sludge burning were observed. The test results are shown in Fig.2 and Fig.3.
It can be seen from Fig. 2 that the boiler thermal efficiency decreases by 0.7% - 1.1% after burning the same proportion of sludge under different evaporation capacity. The boiler efficiency decreases the least under 450 t/h evaporation capacity, and the boiler efficiency decreases the most under 210 t/h evaporation capacity. Fig. 3 shows that the amount of nitric oxide produced in the furnace decreases after the sludge is mixed. At the maximum output, the emission concentration of nitrogen oxides decreases by 20%. When the evaporation capacity of the boiler is 210 t/h, the emission concentration of nitrogen oxides only decreases by 14%.

### 3.2. Effect of sludge blending ratio on boiler efficiency and economy

Fig. 4 shows the effect of sludge blending ratio on boiler economy and pollutant emission characteristics (Rated evaporation capacity). It can be seen from the figures that when sludge blending ratio (heat blending ratio) is 2% - 10%, boiler thermal efficiency decreases by 0.54%, while NO concentration decreases by 305 mg/m³, with a decrease of 40.4%; sulfur dioxide concentration decreases by 220 mg/m³, with a decrease of 11%. After long-term observation and test, the boiler does not have serious ash deposition and coking and large-area high-temperature corrosion under the proportion of 5% ~ 10%. Considering the supply of sludge and the long-term safe and stable operation of the boiler, the boiler can operate stably and safely for a long time under the condition of keeping the heat mixing ratio of sludge at 5%.
3.3. Optimization of the operating characteristics of the boiler after mixing with sludge

The most effective adjustment parameter for operating personnel is oxygen content $\phi(O_2)$. The adjustment of operating oxygen will affect the exhaust gas temperature, fly ash carbon content and combustible gas content, resulting in changes in boiler efficiency; at the same time, changes in $\phi(O_2)$ will also cause changes in furnace temperature and atmosphere in the main combustion zone of the furnace that affecting the emission characteristics of NO and SO$_2$ pollutants. Therefore, it is particularly important to obtain the best $\phi(O_2)$ through optimization and adjustment.

During the test, control the sludge blending ratio to 5%, the boiler evaporation capacity to 400t/h, the oxygen content starts from 2%, one working condition is 0.5%, until the oxygen content reaches 5.5%, and other controllable factors are maintained in the way that operators are most accustomed to. The test results of boiler thermal efficiency and the emission concentrations of NO/SO$_2$ are shown in Fig.5.

Fig. 5 Results of boiler thermal efficiency and the emission concentrations of NO/SO$_2$

The trend relationship between boiler efficiency and $\phi (O_2)$ is fitted to equation (1), and the trend relationship between NO and SO$_2$ emission concentration and $\phi (O_2)$ is fitted to exponential equations (2) and (3).
Where: X is oxygen content, %.

Taking $2.0 \leq x \leq 5.5$ as constraint condition, the minimum limit value of equation (4) is obtained, and $x = 3.61$ is obtained. The results show that the boiler has the best economic and emission characteristics when the $\phi (O_2)$ is 3.61%.

4. Conclusion and suggestions

The results show that the boiler efficiency decreases with the increase of sludge, especially under the condition of low boiler evaporation. After co-firing sludge, the NO emission decreased. The NOx emission concentration decreased the most at the maximum output of boiler, and the emission concentration decreased by nearly 20%. Through optimization and adjustment, it is found that the optimal operation oxygen of the boiler is 3.61% under the condition of 5% sludge blending ratio, and the economy and pollutant emission of the boiler are the best under this oxygen.

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