Application of Plasma Ignition in the Middle Storage-Type Lean Coal-fired Boiler

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Abstract: The paper introduces the realization process of a plasma burner in a middle storage-type lean coal-fired boiler from the aspects of cold leveling test, relevant logic optimization, online monitoring of relevant parameters of the pulverized-coal feeding system and combustion adjustment and proposes corresponding measures for some problems in the plasma burner arising during adjustment. In the case of appropriate coal quality, the successful application of plasma in key links like steam blowing, air-cooled island hot flushing, and no-load test has saved a lot of fuel, presenting a good economic efficiency.

1. Introduction of the System

The boilers of a power plant are DG1150/18.3-II12 subcritical-parameter steam-drum boilers (Type II) produced by Dongfang Boiler, with features of four-corner tangential combustion, primary intermediate reheating, single hearth balanced ventilation, solid slag discharge, semi-enclosed arrangement and all steel structure. The boilers adopt a middle storage-type pulverizing system, each boiler is equipped with three MTZ3872 drum-type steel ball coal pulverizers and each pulverized-coal feeder corresponds to one of the boiler’s burners. There are a total of 16 burners in each boiler, which are arranged on four layers, with four distributed at the four corners of each layer, respectively. The cold air from the primary blower passes through the primary air sector of the tri-sector air preheater, and goes into the pulverized-coal feeding pipe through the primary air duct after heated; the cold air from the blower passes through the secondary sector of the tri-sector air preheater, and part of it, after heated, is mixed with the cold air from the cold air valve in this pipe section, and then enters the coal pulverizer as the conditioning air. The air flow with pulverized coal from the coal pulverizer passes through the coarse pulverized coal separator and the fine pulverized coal separator, and then, the air and the pulverized coal are separated. The separated air passes through the pulverized coal discharging blower, and enters the hearth as the tertiary air. The pulverized coal entering the pulverized coal bunker passes through the pulverized-coal feeder, then mixed with the primary air, and next will be injected into the hearth via the pulverized coal pipe and the burner. In this project, the four burners on the bottom layer are changed to plasma burners and designed with related auxiliary systems. In order to achieve cold boiler pulverizing, an air heater is installed before the hot secondary air enters the coal pulverizer. The design and the check coal parameters of the unit are shown in Table 1, and the main design parameters of the pulverized-coal feeder are in Table 2.
Table 1 Unit Design and Main Parameters of Check Coal

| Item                                | Design | Check 1 | Check 2 |
|-------------------------------------|--------|---------|---------|
| Arb total moisture content (%)      | 8.45   | 8.81    | 7.63    |
| Adb moisture (%)                    | 0.75   | 1.2     | 0.53    |
| Daf volatile content (%)            | 14.1   | 12.5    | 16.6    |
| Arb ash content (%)                 | 29.39  | 33.62   | 26.68   |
| Arb low calorific value (MJ/kg)     | 21.35  | 19.25   | 23.027  |
| Pulverized coal fineness R90 (%)    | 10     | 10      | 10      |

Table 2 Main Design Technical Parameters of Pulverized Coal Feeder

| Item                                | Value            |
|-------------------------------------|------------------|
| Rated output (t/h)                  | 5-15             |
| Pulverized coal density (t/m³)      | 0.65             |
| Impeller diameter (mm)              | 386              |
| Number of impeller teeth            | 12               |
| Spindle speed (r/min)               | 21-81            |
| Transmission ratio                  | 13.5             |

2. Online Air Speed Calibration and Leveling Test

To achieve better combustion and provide the basis for hot adjustment, it is necessary to level the primary air and calibrate the speed thereof on the same layer. Therefore, the air speed was measured and calculated by using the standard pitot tube, and the leveling test for the primary speed on the same layer was carried out through the adjustable shrinkage cavity. The test results before and after leveling are shown in Table 3.

Table 3 Leveling Results of the Primary Air System Corresponding to the Plasma

| Item                                | #1    | #2    | #3    | #4    |
|-------------------------------------|-------|-------|-------|-------|
| Air speed before leveling (m/s)     | 24.1  | 25.9  | 23.3  | 24.7  |
| Air speed after leveling (m/s)      | 25.0  | 24.8  | 24.0  | 24.3  |
| Deviation after leveling (%)        | 2.0   | 1.1   | -2.1  | -1.1  |

3. Optimization of Relevant Logic

To implement the pulverizing system’s plasma operation mode and the FSSS interface, the DCS logic distinguishes the "plasma ignition mode" and the "normal ignition mode". The logic about the plasma ignition mode is as follows:

(1) In the coal ignition permission, there is an ignition source (ignition source: means the adjacent fuel layer has been put into operation, or the adjacent coal layer is operating and the boiler load is >25%, or the load is >60%; lower-layer ignition source in the plasma mode: the plasma system is put into operation)
(2) In the plasma mode, the plasma shutdown interlocking stops the corresponding pulverized coal feeder.
(3) When the RB logic is triggered, the interlocking activates the plasma burner.
(4) After MFT is triggered, the plasma igniter trips through logic and hard wiring.
(5) When the hearth purging conditions increase, all plasmas are stopped.
(6) Ignition failure increasing: If no flame is detected 3s after the pulverized coal feeder is started, it is considered that the ignition has failed.

4. Hot Ignition Test of Plasma

4.1 Operation and Control of the Pulverizing System

1) Based on the incoming types of coals, the one with the highest possible volatile content should be used, and the type of the used coal is very important to ensure the success of plasma ignition. If the volatile content is excessively low, it will be not conducive to ignition.

2) During the pulverizing before the boiler’s initial ignition, the auxiliary steam should be used to heat the air heater in order to increase the hot air temperature and reach the pulverizing-start condition. Only when the hot air temperature is raised to 150 °C, can the pulverizing system start work. During the pulverizing, the fuel gun corresponding to the tertiary air nozzle should be activated, so that the pulverized coal carried by the tertiary air burns; or the uppermost-layer fuel gun should be activated before the boiler’s initial pulverizing. After the fuel is injected, the hot air temperature should be raised to 150 °C as soon as possible to reach the pulverizing-start condition.

3) The plasma ignition system should not be activated before the pulverized coal level in the pulverized coal bunker is up to 1.5 meters; if the pulverized coal level is too low, it may cause unevenness of the pulverized coal from the primary air, affecting the combustion stability.

4) Adjust the pulverizing outlet temperature to make it be stable above 90 °C. The pulverizing inlet negative pressure should be -200 to -300 Pa, and the differential pressure at the inlet and outlet should be 2.0 to 3.5 KPa.

5) By adjusting the opening of the coarse pulverized coal separator, make the fineness of the pulverized coal meet the design requirements.

4.2 Control of the Pulverized Coal Feeder at the Beginning of Ignition

In order to meet the requirements of plasma ignition in terms of the concentration and air speed of the pulverized coal, the temperature and pulverized coal concentration after the mixing of the air and pulverized coal should be calculated by using the mass conservation and energy conservation equations. A differential pressure sensor is installed on the primary air pipe, and a differential pressure signal is generated when the fluid flows through, and a primary air speed can be obtained according to the correction of the gas state equation test.

\[ \rho P_2 = \frac{2\Delta P}{K} \]  

Where,
\( \Delta P \): Differential pressure of the differential pressure sensor (Pa);
\( \rho \): Hot air density (kg/m³);
\( K \): Flow rate calibration factor;

Suppose that the speed and output of the pulverized-coal feeder are linear, then the function of the relationship between the output of the pulverized-coal feeder \( Q_2 \) and the speed of the same is given in Table 2.

\[ Q_2 = 10 \frac{\nu - 283.5}{13.5(81 - 21)} + 5 \]  

According to the mass conservation and energy conservation equations, we obtain
Where,

\[ Q_1(t_1 - t)c_1 = Q_2(t - t_2)c_2 \]  \hspace{1cm} (3)

\[ t = \frac{c_1Q_1t_1 + c_2Q_2t_2}{c_1Q_1 + c_2Q_2} \]  \hspace{1cm} (4)

Where, Q1 and Q2 are air and pulverized-coal mass flows (t/h) in the pulverized pipe, respectively;

c1 and c2 are the mean specific heat of the air volume and the pulverized coal in the pulverized coal pipe (KJ/Kg), respectively;

t, t1 and t2 are the pre-mixing temperatures of the air/pulverized coal mixture, the air and the pulverized coal (°C); t1 and t2 may be the temperature of the hot air feeding the pulverized-coal, and the temperature of the pulverized coal chamber, respectively, after the air preheater is used.

The expression of the pulverized coal concentration is as follows:

\[ \mu = \frac{Q_2}{Q_1} = \frac{c_1(t_1 - t)}{c_2(t - t_2)} \]  \hspace{1cm} (5)

Where, \( \mu \) : the content of pulverized coal in one unit mass of air (kg/kg);

Through the use of the DCS configuration, the on-line monitoring on the primary air speed, pulverized coal feeding volume and concentration as well as the temperature of the air mixed with the pulverized coal may be achieved, so that the primary air speed and the pulverized coal concentration can fully meet the plasma ignition requirements. The post-mixing temperature may be used to correct the deviation caused by the nonlinearity of the pulverized coal feeder. It can be known from Equation 2 that the temperature after the air-pulverized coal mixture from the four primary air pipes will have no or small deviation only Q2 tends to be equal in the preconditions that the air volume Q1 in the pipe is fixed. Therefore, the final speed of the pulverized coal feeder is controlled to be within the optimum range of the pulverized coal concentration, and the post-mixing temperatures of the four burners on the same layer are substantially equal.

4.3 Various Adjustments after Plasma Start

In order to ensure the plasma ignition effect, the openings of the coarse and fine pulverized coal separators should be adjusted to a small value to ensure the fineness of the pulverized coal;

Activate the plasma igniter and adjust the power to about 110KV; start the pulverized coal feeder, and quickly adjust its speed to the optimum pulverized coal concentration, which not only ensures the stable combustion, and reduces the loss caused by incomplete combustion, but also avoids excessively-fast temperature and pressure rise. In the initial stage of the boiler’s ignition start, the applicable range of the fired pulverized coal concentration is 0.36-0.52kg/kg, and the minimum is not less than 0.30kg/kg. Generally, maintaining the minimum speed of 280r/min can meet the requirements;

1. In the initial stage of the boiler’s cold start, the primary air speed of the plasma burner should be kept at 19-22m/s. During the hot-state or low-load stable combustion, the primary air speed should be kept at 24-26m/s. Given the safety is ensured, the air speed should be reduced as much as possible, but it should not be lower than 18m / s;

2. Adjust the surrounding air of the plasma burner to maintain the opening of the surrounding air valve at 15%.

When the entire starting is implemented with the plasma ignition system, the cooling water system should be put into operation to control the steam temperature in addition to the necessary combustion adjustment.
4.4 Problems and Treatment during Plasma Ignition

1) During the initial start, a large volume of auxiliary steam is used for the air preheater’s soot blowing, water supply heating, etc., so the hot air needs to take a long time to reach the pulverizing-start requirement, and even the requirements cannot be met in winter. Therefore, the fuel should be put in first during the initial start, especially in winter, so that the hot air temperature meets the pulverizing-start requirements. Besides, the temperature in the boiler increases, the burn-off rate of the pulverized coal will rise, thus reducing the possibility of spontaneous combustion of the pulverized coal in the tail flue.

2) The coal-fuel co-burning time is long. Unlike the direct-blowing type system, the tertiary air of the middle-storage pulverizing system carries the pulverized coal with a concentration of about 10-20% when entering the boiler hearth. If no reliable measures are taken, the risk of secondary combustion in the tail flue, air preheater and electric dust remover will increase. In the low-load pulverizing process, the corresponding fuel gun must be activated so that the pulverized coal carried by the tertiary air can burn. Therefore, there must be a fuel gun to support combustion during the low load pulverizing process, improving the burn-off rate of the pulverized coal in the boiler. A reasonable operation method is that the pulverizing system is fully operated when the pulverizing conditions are available, and the recirculation valve is opened as much as possible, and after the pulverized coal bunker reaches a high level, the pulverizing system is stopped and the corresponding oil gun is stopped as well.

3) In the low-load pulverizing process, the flame center moves up due to the heat output of the pulverized coal and the corresponding oil gun, causing the steam temperature is high. In this case, the cooling water needs to be used to meet the temperature requirements of the steam blowing pipe, the air-cooled island flushing, and steam turbine rolling. Before the initial ignition, therefore, the cooling water of the superheater and reheater must have the operating conditions to meet the requirements of steam temperature control.

4) Due to a large number of elbows near the plasma burner, the pulverized coal is separated based on concentration before entering the burner. When the air speed is low, the pulverized coal deposition occurs. With the increase of the load, coking occurs and the burner output is affected. Sometimes, the operation of the burner has to be stopped to clean coke blocks; in order to ensure the safe operation, the air speed should be controlled to be no less than 20m/s, and also, in the case of stable combustion, the output of the pulverized coal feeder should be appropriately reduced.

5) There is a certain burning instability because of discontinuous feeding of the pulverized coal; the boiler negative pressure fluctuates greatly, reaching 800-700Pa, which may affect the safety of the on-site fire-fighting personnel. Several measures have been taken for the feeding instability of the pulverized coal: a) Increase the outlet temperature of the coal pulverizer to 105 °C; b) Thoroughly clean the internal debris of the pulverized coal chamber; c) Maintain a higher pulverized coal level and uniform left and right; and d) Optimize the logic to achieve the alarming against the discontinuous feeding of the pulverized coal feeder.

6) Since the design is carried out for a lean coal fired boiler, the combustion is unstable under the designed coal quality if the plasma ignition is adopted. In order to increase the burn-off rate to promote the combustion stability, the plasma power is increased, but which brings problems such as plasma cylinder coking, affecting the safety of the boiler. If a plasma burner is activated, the coal with the dry-ash-free volatile content of more than 18% should be used as much as possible, the requirements of plasma for the coal quality may be met by using the mixed coal.

7) The designed type of coal has a low volatile content, and there is no conditioning air for the pulverizing air or the pulverized coal feeding air. Therefore, the coal with a high volatile content is often used during the starting and commissioning period and upon long-term loaded operation, so that the plasma combustion is stable, achieving fuel-saving; when the load reaches the minimum stable combustion load, the designed type of coal should be used, the operation of plasma will be stopped, and the system is switched to the normal combustion wear, avoiding the problems like spontaneous combustion, coking, etc. in the pulverized coal pipe due to the excessive temperature of the air/pulverized coal mixture.
5. Summary

(1) When the coal with a high volatile content is used, the use of the plasma burner during the commissioning period of the basic construction can save a lot of fuel and reduce the operating cost of the power plant, thereby basically meeting the requirements of each commissioning stage. However, the plasma burner technology for lean coal needs to be further improved.

(2) The plasma burner has rigorous requirements on the concentration of pulverized coal at low load, but the discontinuous feeding frequently occurs in the pulverized coal feeder at the initial start stage, and even which may cause a certain degree of deflagration in the boiler. Taking reliable measures to eliminate the discontinuous feeding of the pulverized coal feeder can improve the boiler’s safety to a certain extent when the plasma burner is put into operation.

(3) During the process from the unit ignition to the load application, it is necessary to control the levels of the coal bunker and the pulverized coal bunker. Adjusting the control parameters of the coal pulverizer according to the coal quality will bring a large amount of work load to the operating personnel, and the risk of the equipment is high in terms of safety.

References

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