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Experimental Study on Effects of Pulverizer Outlet Parameters on Boiler Combustion

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Abstract. In order to obtain the effects on combustion in boiler when some parameters such as pulverized coal fineness, velocity of primary air mixed pluvesized coal particles change, testing on a 300MW power plant. The results illustrate that when fineness rised, temperature of gas center 0.4 meter apart from burner reduced to 536℃, unburned carbon in fly dust rised 4.1% and unburned carbon rised 6.8%, average temperature located A burner cross section decreased, average temperature located C burner cross section was almost invirant, average temperature located E burner cross section rised, average temperature located 30.5 meter cross section decreased; when the flow velocity rised, temperature of gas center 0.4 meter apart from burner reduced to 346℃, unburned carbon in fly dust rised 3.6% and unburned carbon didn't have a obvious rule, average temperature located A burner cross section increased before decreasing, average temperature located C burner cross section rise alittle, average temperature located E burner cross section rised, average temperature located 30.5 meter cross section rised. Both parameters rised against ignation, unburned carbon in fly dust both rised, the temperature variation in boiler were different.

Keywords: boiler, combustion, ignation, temperature in boiler, fineness, velocity of primary air mixed pulverized coal particles.

1. Introduction

China's coal consumption accounts for 65-70% of national energy consumption for a long time [1]. With China's rapid economic development, coal consumption continues to increase. Coal, as a non-renewable resource, needs highly efficient environmental protection to be used.At present, 60% of coal consumption is used for thermal power generation and heating. It is the main direction of coal energy conservation that study how to improve combustion efficiency in boilers. The hot air carrying pulverized coal enters the furnace at a high speed from the combustor nozzle, pyrolyzes, fires, burns and transfers the heat to the working medium. For the air powder mixture with different parameters, the combustion situation in the furnace is different. It is important to study the Effect of the parameter change on the boiler operation to realize the energy saving and emission reduction work of the boiler.

The study of pulverized coal combustion characteristics usually includes thermal balance method [2], one-dimensional subsiding furnace method [3], numerical simulation [4,5], etc. Zhao Yunhua et al [6] studied the effect of pulverized coal concentration on ignition and combustion. Nie Xin et al [7] conducted a multi-coal ignition study on a 0.35 MW experimental rig. Qin Yuqi et al [8] conducted an experimental study on inferior coal ignition and steady combustion and Xu Kailong et al [9] simulated on a plane-carrying flow reactor that the actual boiler combustion studied the effect of a air-oxygen concentration on the fire. Li Wenhua et al. [10] studied the effect of the temperature of the mixture on the combustion of the boiler on a 300MW boiler.

In this paper, a 300 MW unit is used to study the effects of pulverized coal fineness and powder mixture speed in the powder pipeline on the ignition, combustion and burnout of pulverized coal in the furnace. The main measurement and analysis of the pulverized coal gas flow center at a certain distance from the combustor outlet temperature, temperature field inside the furnace and carbon content of ash.

2. Boiler Equipment System Condition

A power plant boiler, SG-1025/17.5-M881 subcritical parameter drum boiler, single furnace, control cycle, one intermediate reheat pulverized coal furnace, tangential firing, solid slagging, open structure layout, is produced by Shanghai Boiler Factory Co., Ltd.,. The boiler is equipped with 5 MPS coal pulverizers, which adopts a medium-speed coal pulverizer direct-blowing powder feeding system and five layers of primary air nozzles, of which four layers can be operated with BMCR.

The combustor arrangement is shown in Figure 1. The boiler adopts four-corner arrangement and concentric reverse tangent combustion mode. The combustor nozzle structure adopts a pattern in which the primary air outlet is surrounded by a peripheral air and a secondary air nozzle is arranged at intervals. The uppermost combustor has an elevation of 26.2 m, the top is provided with a two-layer over firing air (OFA) nozzle, and a two-layer OFA nozzle (not shown in Fig. 1) is provided at 6700 mm of the primary air nozzle distance from the upper part of the combustor.

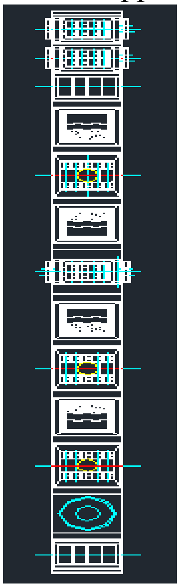

Fig. 1 Combustor Arrangement

3. Experimental Research

In the two experiments, the A, B, C, and D coal pulverizers are operated under the load of 290 MW, and OFA of the upper part of the combustor is opened in four layers. The output of each coal pulverizer is as uniform as possible. The analysis results of the coal samples used are shown in Table 1.The center temperature of the pulverized coal gas flow at a distance of about 0.4 m from the spout is measured at the view hole using an air bleed thermocouple, and the A-layer combustor #2 angle is selected at the experimental position. The distance measurement is performed in advance during the shutdown, and the air bleed thermocouple is fixed on the furnace platform.The infrared pyrometer is used to measure the temperature inside the furnace at the fire hole. The temperature of each layer is taken as the average value of the four measuring points of the layer. The experimental position is selected from the A layer, the C layer, the E layer and the 30.5 m platform. At the inlet of the air preheater A and B, the fly ash is collected by the constant velocity sampling method and averaged; the slag is sampled multiple times at the outlet of the dry slag removal machine [11].

The effect of fineness of pulverized coal on the boiler is studied under the condition of air speed of 25 m/s in powder pipeline and temperature of 85 °C in air powder mixture. Adjust the fineness of the pulverized coal through the separator opening degree, and select the working conditions of the separator opening degree of 30%, 38%, 45%, 53%, and take a powder pipeline for each pulverizer to carry out fineness of pulverized coal isokinetic sampling. The analysis results are in detail shown in Table 2.

The effect of the air speed in the powder pipeline on the boiler was studied under the condition that the temperature of the mixture of the air powder is 85 ° C and the opening degree of each separator is 45%. Under the premise that the secondary air volume is constant, the air speed in the powder pipeline is changed by adjusting the output of the primary fan. Before the experiment, the dial value of each powder pipeline is measured, the dial value was calibrated and the air speed of each of the four powder pipelines is leveled. The speed of each powder pipeline is adjusted as much as possible by using the shrinkage hole and the opening and closing of the hot and cold damper flaps of each grinding inlet and close to the experimental value. The value is displayed on the dial after calibration. In order to ensure the safe operation of the pulverizing system, this experiment selects three working conditions of 23 m/s, 26 m/s and 29 m/s. The air speed in each powder pipeline is shown in Table 3.

Table 1. Proximate and Ultimate Analysis of Coal Sample

	Proximate analysis(%)					Net calorific value (kJ/kg)	Elemental analysis (%)				
	M_t	M_{ad}	A_{ad}	V_{ad}	FC_{ad}	$Q_{net.ar}$	C_{ar}	H_{ar}	N_{ar}	$S_{t,ar}$	O_{ar}
Ⅰ	7.92	1.33	22.46	28.84	47.37	22398	61.90	3.64	0.92	0.81	7.36
Ⅱ	7.60	0.70	31.36	20.95	46.99	20120	52.96	3.09	0.89	1.20	5.52

Table 2. The result of Pulverized Coal Fineness (R_{90})

Pipeline No.	A1/%	B1/%	C2/%	D1/%
Work Condition 1	10.8	13.6	8.5	10.4
Work Condition 2	17.6	18.9	14.5	16.5
Work Condition 3	23.6	20.7	21.8	20.2
Work Condition 4	31.3	33.6	29.7	28.6

Table 3. Flow Velocity in Pipeline (m/s)

Pipeline No.	A1	A2	A3	A4	B1	B2	B3	B4
Work Condition 1	22.1	22.9	23.4	23.0	23.6	23.0	22.3	23.1
Work Condition 2	25.6	25.9	26.4	26.4	26.6	25.5	25.6	26.1
Work Condition 3	28.5	28.7	29.6	29.0	29.4	28.9	29.0	29.1
Pipeline No.	C1	C2	C3	C4	D1	D2	D3	D4
Work Condition 1	22.5	23.5	23.2	22.3	22.7	21.9	22.4	23.6
Work Condition 2	25.8	26.4	26.4	25.7	25.6	24.5	24.7	25.6
Work Condition 3	28.7	29.4	29.2	28.9	28.7	27.9	27.8	28.2

4. Experimental Results and Discussion

4.1 Effect of Fineness of Pulverized Coal on Boiler Combustion

4.1.1 Effect of Fineness of Pulverized Coal on Center Temperature of Pulverized Coal Gas Stream

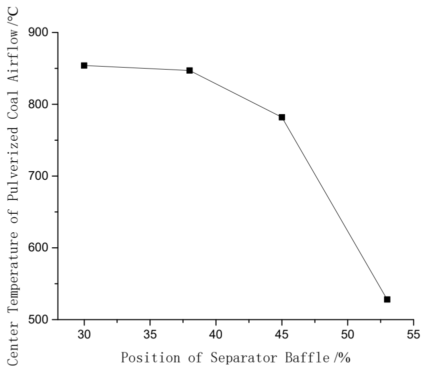

Fig. 2 Temperature Variation in the Center of Pulverized Coal Airflow

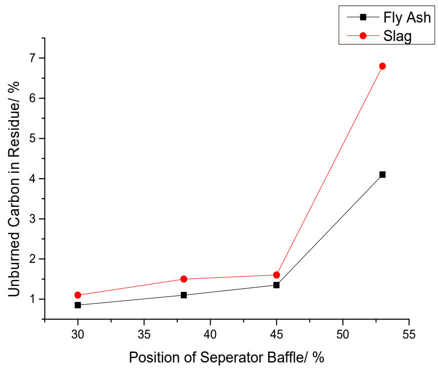

Fig. 3 Unburned Carbon Variation in Fly Ash and Slag

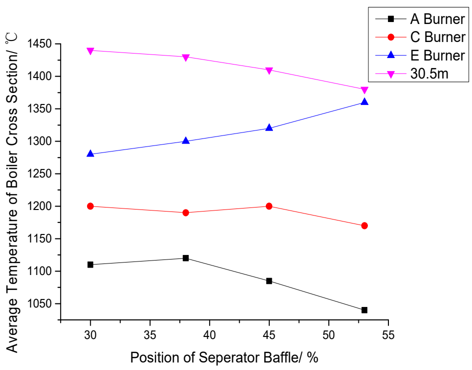

Fig.4 Average Temperature Variation of Boiler Cross Section

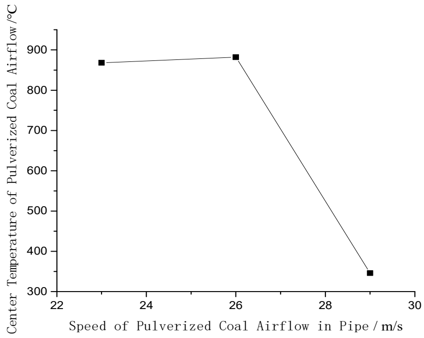

Fig.5 Temperature Variation in the Center of Pulverized Coal Airflow

It can be seen from Fig. 2 that, with the opening degree of the coarse powder separator baffle opening, the average particle size of the pulverized coal becomes larger, and the temperature of the pulverized coal gas flow center at a distance of 0.4 m from the spout is declining. The temperature at the 30%, 38% and 45% opening is slightly decreased, but, around 800 °C, the pulverized coal gas flow has been burned at this position. The temperature at this position is as low as 536 °C at 53% opening, indicating that the pulverized coal gas flow center has not been significantly ignited under this working condition. Pulverized coal ignition is generally divided into four times [12]: heat flow penetration time, pulverized coal heating time, combustible material mixing time and reaction induction time. The increase of particle size leads to O2 diffusion to the internal time of the particles, and the heat of the surface of the particles transferred to the interior is slowed down, and CO is mainly generated by the carbonyl, ether bridge, and oxygen-containing heterocyclic ring fracture [13, 14], which are not conducive to the formation of combustible CO and the reaction induction time is delayed.

4.1.2 Effect of Carbon Content in Ash

Whether highly efficient of the combustion in the furnace is reflected in the carbon content of fly ash and slag. The experimental results are shown in Figure 3.

It can be seen from Fig. 3 that, as the opening degree of the baffle increases, the fineness of the pulverized coal increases, and the carbon content of the fly ash and the slag increases accordingly. When the separator baffle opening degree is from 30% to 38%, the carbon content of fly ash and slag increases less, and when the baffle opening degree is from 45% to 53%, the carbon content increases significantly. The carbon content of fly ash and slag reached 4.1% and 6.8% in the 53% baffle opening degree respectively, indicating that the combustion efficiency in the furnace is very low, the degree of combustion deterioration is serious, and more black unburned particles are clearly seen in the fly ash. After the slag was opened, it was found that there were many black particles in the interior, indicating that a part of the large-sized pulverized coal was not included in the slag due to the increase in particle size.

4.1.3 Effect of Temperature Field in the Furnace

It can be seen from Fig. 4 that, as the opening degree of the separator baffle increases, the cross-section temperature of the A-layer combustor decreases, and the cross-section temperature of the C-layer combustor does not change significantly. The E-pulverizer is not opened during the experiment, and the combustor of E layer is equivalent to the upper part of the combustion zone during the experiment. The temperature of the section of the layer shows a clear rise, while the section temperature at 30.5 m decreases.

The pulverized coal injected into the furnace receives the convective heat transfer of the high-temperature flue gas and the radiant heat of the furnace, and then rapidly heats up. At the same time, the pulverized coal jet is rapidly dispersed in the combustion area with high oxygen concentration, and some of the pulverized coal with smaller particle size multiphase ignition occurs directly to release heat in a high temperature environment [15]. The rapid pyrolysis of volatiles of larger particle size pulverized coal particles produces CO, CxHy and other combustible small molecules is conjunction with the fire homogeneous and heterogeneous with pore diffusion and adsorption O_2 [16] and the release of heat further promotes the formation of combustible gases in the coal. According to the analysis, although the cross section of the A-layer combustor is in a high temperature region, as the opening degree of the baffle increases, the particle size of the pulverized coal becomes larger, the diffusion and adsorption capacity of O_2 decrease, and the volatiles contained in a part of the large granular pulverized coal are too late to the participation reaction. Namely, it is carried to the upper area by the airflow, the O_2 in the fixed carbon is more difficult to diffuse, the combustion is relatively difficult and the burning time is long. The delay of ignition and combustion leads to the temperature drop of the A-layer section; The upward delay of the ignition has little effect on the combustor area of the C-layer, the layer is still in the area where the pulverized coal is ignited and fully burned, the pulverized coal emitted from the combustor of the layer is reduced in heat, the unburned pulverized coal in the lower combustor releases a certain amount of heat in the layer to make up for the loss, the total heat released is basically no change, the cross-section temperature has no obvious change rule; with the increase of combustible particles in the lower combustion zone, the cross-section of the E-layer combustor region increases the thermal heat, and the cross-section temperature increases obviously; the temperature of the furnace cross-section at 30.5 m decreases. It may be that the oxygen concentration in this area is low but not measured, and the residual pulverized coal and combustible gas react less, and the heat released is not enough to offset the heat absorption of the water wall. Therefore, the temperature decrease.

4.2 Effect of Air Speed in Powder Pipeline on Boiler Combustion

4.2.1 Effect of Air Speed in Powder Pipeline on Center Temperature of Pulverized Coal Gas Stream

It can be seen from Fig. 5 that, as the air speed in the powder pipeline becomes larger, the center temperature of the pulverized coal gas flow at 0.4 m decreases, and the temperature change in the position of the powder pipeline is not large above 800 °C when the air speed in the powder pipeline rises from 23 m/s to 26 m/s, which indicates that the pulverized coal in this position has been ignited under the two working conditions. When the air speed in the air duct rises from 26 m/s to 29 m/s, the temperature of the position drops sharply to 346 °C, indicating that the pulverized coal gas flow is still no obvious fire in this position under this condition. The experimental second coal has a Vad of 20.95% and a Vdaf of 30.84%. The ignition performance is relatively difficult compared with the experiment. The air temperature in the powder pipeline is 85 °C. The increase in air speed indicates that the amount of cold air entering the furnace increases, and the air powder mixture needs to absorb more heat. The temperature rise becomes slower, which causes the rate of coal pyrolysis flammable gas to decrease, reduces the intensity of homogeneous reaction and the fire is delayed accordingly.

4.2.2 Effect of Carbon Content in Ash

It can be seen from Fig. 6 that, as the air speed of the powder pipeline increases, the secondary air volume does not change, the gas flow rate in the furnace becomes larger, and the O_2 concentration in the furnace is increased to facilitate the reaction of combustibles, but the residence time of the pulverized coal particles in the furnace is reduced, and it is not conducive to the burning of fixed carbon in fly ash and the carbon content of fly ash is rising. In particular, when the 1 air speed is increased from 26 m/s to 29 m/s, the carbon content of fly ash increases from 1.3% to 3.6%; the amount of carbon in slag increases after the decrease, the reason may be that some pulverized coal particles do not have enough kinetic energy to enter the strong combustion area and fall into the slag pool from the near-water wall area. In addition, the air speed is too low, which is not conducive to O_2 adsorption and diffusion, and the oxygen concentration of the internal reaction of the particles in the area is limited to diffusion combustion; when the air speed is too high, the pulverized coal particles are not easily firing into the slag pool.

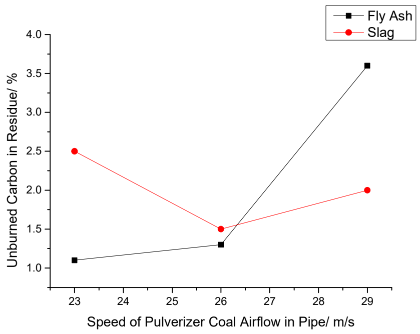

Fig.6 Unburned Carbon Variation in Fly Ash and Slag

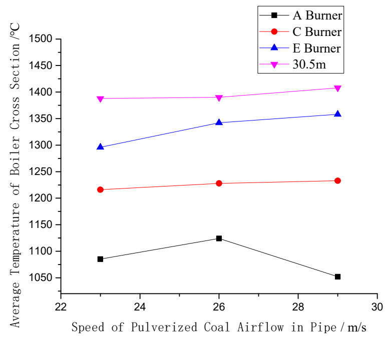

Fig.7 Average Temperature Variation of Boiler Section

4.2.3 Effect of Temperature Field in the Furnace

It can be seen from Fig. 7 that, as the velocity of the air-powder mixture increases, the average temperature of the cross-section of the A-layer combustor first rises and then decreases. The average temperature of the cross-section of the C-layer combustor increases, but the increase is not large. The average temperature of the section of E-layer combustor shows a rising law, and the average temperature of the section at 30.5 m rises.

Pulverized coal particles generally follow a homogeneous reaction of volatiles and a heterogeneous reaction of fixed carbon. The analysis shows that although the cross section of the A-layer combustor is in the high temperature region, as the airflow velocity in the powder pipeline rises from 23 m/s to 26 m/s, the cold air volume becomes larger, the temperature in the reaction zone is slightly lowered, and the ignition is delayed, but the reaction zone is delayed. The oxygen concentration increases, the O_2 diffusion rate is fast, and the pulverized coal enters the diffusion combustion reaction very quickly after the ignition. The release of heat causes the average temperature of the section to rise. When the air speed continues to rise to 29 m/s, the pulverized coal gas flow rises and the heat rises. The time is postponed, although the oxygen concentration is increased, the time for the pulverized coal particles to stay in the region is shortened, and the heat is not released to the upper layer, so the cross-section temperature of the layer is decreased; it is not large that the increase of the air speed in the powder pipeline affects the combustor area of the C-layer. The layer is still in the area where the pulverized coal is ignited and fully burned. The pulverized coal emitted by the combustor of this layer is delayed and releasing heat decreases. The lower area comes with unburned pulverized coal particles, CO and other combustible gases continues to burn in the layer. It releases amount of heat to make up for the previous loss, the total heat released is basically unchanged and the cross-section temperature rises less; the combustible particles increase with the lower combustion zone, The cross-section temperature of the E–layer combustor section is continuously increased, and the cross-section temperature is obviously increased; the cross-section temperature rises at 30.5 m, which may be due to the short combustion time of the lower combustibles, and primary air speed improves the increase of oxygen concentration, which promotes the further reaction of the fuel. The area is released by the increase in heat.

5. Conclusion

(1) The fineness of different pulverized coal has a great effect on the operation of the boiler. With the increase of the average particle size of the pulverized coal, the temperature of the pulverized coal gas flow center decreases significantly distance of 0.4 m from the nozzle of the combustor, and the pulverized coal ignition distance become significantly longer on the opening degree of 53%.; the temperature field of the furnace has a certain change, the average temperature of the section of the combustor in the A layer decreases. The average temperature of the section of the unoperated E-layer combustor increases and the average temperature of the section of the platform at 30.5 m of the furnace decreases; the carbon content of the ash has clearly rising law and the pulverized coal fineness increases to a certain value. The combustible content rises sharply and the burn-up performance is very poor.

(2) The speed of different air powder mixture has a great effect on the operation of the boiler. With the increase of speed, the temperature of the pulverized coal gas flow center decreases significantly distance of 0.4 m from the nozzle of the combustor and when the gas flow velocity of the powder pipeline is 29 m/s, firing distance of pulverized coal become longer; The temperature field in the furnace box changes obviously. The average cross-section temperature of the A-layer combustor first increases and then decreases. The average temperature of the E-layer and the 30.5 m cross-section shows an increasing law. The carbon content of the ash changes significantly, and the fly ash combustible content increases significantly and regularly. When the gas flow rate in the powder pipeline is increased from 26 m/s to 29 m/s, the carbon content suddenly increases and the flammable content of the slag first decreases and then rises.

(3) The increase of the two parameters of coal fineness and air powder mixture speed is not conducive to the ignition of pulverized coal and the burning of pulverized coal, but the variation law of furnace box temperature field is inconsistent.

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