

# Study of flue-gas temperature difference in supercritical once-through boiler

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**Abstract.** The 600 MW coal-fired once-through Boilers with opposed firing at a power plant are found to experience marked temperature variation and even overtemperature on the wall of the heating surface as a result of flue-gas temperature (FGT) variation in the boiler. In this study, operational adjustments were made to the pulverizing, combustion, and secondary air box systems in these boilers, in order to solve problems in internal combustion. The adjustments were found to reduce FGT difference and optimize the boiler's combustion conditions. The results of this study can provide a reference for optimization of coal-fired boiler of the same type in similar conditions.

## 1. Introduction

The 600 MW coal-fired once-through boilers at the plant of interest are supercritical once-through boiler of DG1913/25.4-II3 type manufactured by the Dongfang Boiler Group Co., LTD. They are characterized by opposed-firing, primary reheat, a single furnace, balanced draft, and a "IT"-shape full suspension structure. The design coal for these boilers is the bituminous coal produced in the Huainan mining area. The coal pulverizing system in each boiler consists of six positive-pressure, direct-firing pulverizers with cold primary air blowers, six ZGM113G medium-speed mills, and 24 low-NO<sub>x</sub> swirl burners of HT-NR3 type, which are installed at three levels on the front and rear furnace walls. An array of over-fire air (OFA) ports is installed above the upper burners to reduce production of NO<sub>x</sub>. The main design parameters and the main design coal of the boiler are as shown in Table 1 and Table 2.

Since the power plant went into operation, the back end ductwork of the boiler have experienced continued FGT difference of about 50° C as well as marked oxygen content variation. Under varying operating conditions, the regions between superheaters and reheaters frequently show overtemperature, affecting the operation of heating surface and combustion efficiency. Recent research has suggested that residual rotation of flue gas is the root cause of the FGT difference [1-2]. Therefore, this study tried to control the residual rotation of flue gas in order to reduce the FGT difference in back end ductwork, to prevent overtemperature of the heating surface and thereby improve boiler efficiency. To this end, operational adjustments were made to the boilers' pulverizing, combustion, and secondary air box systems.



**Table 1.** Main design parameters of the boiler.

Item	Unit	Boiler Maximum Continuous Rating	Turbine Heat-Acceptance
Superheated steam flow	t·h <sup>-1</sup>	1913	1675.58
Superheated steam pressure	MPa	25.5	25.2
Superheated steam temperature	° C	571	571
Reheat steam flow	t·h <sup>-1</sup>	1583.71	1398.5
Reheat steam pressure	MPa	4.24	3.77
Reheat steam temperature	°C	569	569
FGT at furnace outlet	°C	1029	994
Flue gas exhaust temperature.	°C	127	121
Boiler efficiency	%	93.07	93.29

**Table 2.** Main design coal for the boiler.

Item	Unit	Design coal	Calibration coal 1	Calibration coal 2
Total moisture	%	8.00	9.45	5
Ash content	%	30.68	35.60	28.55
Volatile content	%	38.88	24.29	33
Lower calorific value	MJ·kg <sup>-1</sup>	19.82	17.50	22.01
Grindability (HG)	/	73	64	75
Deformation temperature	° C	>1500	>1500	1480
Carbon	%	50.89	46.15	56.86

## 2. Experimental

The optimization of the milling system is mainly based on the optimization of the operation mode of the previous milling system. Firstly, the wind speed of the coal mill is optimized, and then change the amount of coal, loading force and fold to the baffle opening, through the adjustment of test, By adjusting the test to find out the best relationship between the coal briquettes, the coal and the loading force, fineness of pulverized coal (R90) can less than 20% under different working conditions, shorten the coal into the furnace Burning time, reducing the height of the furnace flame[3-4].

The adjustment of the combustion system mainly adjusts the secondary air, the secondary air and the central air volume in the burner. The whole burner is optimized by the optimization of the single burner to adjust the balance of all the burner pulverized coal concentration and the air volume balance the back end ductwork gas flow deviation[5], and ultimately the back end ductwork on both sides of the flue gas parameters are basically the same.

The secondary air box wind distribution optimization test mainly reduce the furnace flame height and the furnace gas temperature of the superheater area, reduce the temperature of the superheater heating surface wall by optimizing the secondary bellows baffle opening.

### 2.1. Pulverizing system optimization experimen

After operational optimization of the previous pulverizing system, the flame height increased [6], the FGT varied across the furnace, and the boiler showed significant FGT difference, during operation of the upper and middle levels of the pulverizing system. This optimization experiment was conducted to adjust the coal fineness produced by the 6 pulverizers in #1 boiler so that the R90 reached 15-20%. Each pulverizer was tested under two conditions. In Condition 1, the feeding rate of coal and the grinding force applied were constant and the opening of classifier vane was adjusted to observe how

the coal fineness varied with classifier vane opening. In Condition 2, the classifier vane opening did not change and the feeding rate of coal was adjusted to investigate the relationship between feeding rate and fineness of coal; the grinding force applied by the mill changed automatically with the feeding rate of coal.

### 2.1.1. Effect of classifier vane opening on coal fineness

To examine the performance of the classifier vanes attached to the mills and the relationship between classifier vane opening and coal fineness, the output of each mill was adjusted to the level achieved when the boiler operated at full load during the experiment. The primary air velocities at the mill outlets were maintained between 20-25 m·s<sup>-1</sup>. Three vane openings were used in this experiment: 40%, 45%, and 50%. The experimental results are shown in Table 3.

**Table 3.** Experimental results for different openings of classifier vanes in Mill A-F.

vane opening	Mill A		Mill B		Mill C		Mill D		Mill E		Mill F	
	R90	R20	R90	R20	R90	R20	R90	R20	R90	R20	R90	R20
		0		0		0		0		0		0
40%	12.1	0.7	11.3	0.59	10.3	0.4	8.6	0.48	13.3	0.4	6.12	0.04
	1		6						2			
45%	14.0	0.76	14.6	0.66	11.4	0.04	12.1	0.52	13.4	0.54	14.6	0.33
	4		8				2				8	
50%	19.8	0.84	15.6	0.76	13.2	0.47	16.2	0.8	16.4	0.69	16.9	1.2
	5				6		4		2		2	

Remark: Mill outputs 50 t·h<sup>-1</sup>, Grinding force 11Mpa

The experimental results reveal good linearity of the relationship between classifier vane opening and coal fineness at a feeding rate of 50 t·h<sup>-1</sup>. As the vane opening increased, the coal fineness tended to reach the desired levels: R90 = 15-20%, indicating that the classifier vanes can effectively control coal fineness. To optimize the pulverizing system, we suggest that the classifier vane opening be adjusted to 50% for the mills.

### 2.1.2. Effect of Mill output on coal fineness

During the experiment, the coal fineness at four different mill outputs, 40 t·h<sup>-1</sup>, 45 t·h<sup>-1</sup>, 50 t·h<sup>-1</sup>, and 55 t·h<sup>-1</sup>, was observed in order to analyze the relationship between Mill output and coal fineness. The vane opening was set at 50% and the primary air velocity maintained between 20-25 m·s<sup>-1</sup>. Table 4 presents the experimental results.

**Table 4.** Experimental results for different outputs of Mill A-F.

Mill outputs	Grinding force	Mill A		Mill B		Mill C		Mill D		Mill E		Mill F	
		R90	R200	R90	R200	R90	R200	R90	R200	R90	R200	R90	R200
45t·h <sup>-1</sup>	10.7 MPa	12.1	0.7	18.7	1.5	14.7	0.7	14.9	0.6	7.7	0.3	15.7	1.8
50t·h <sup>-1</sup>	11.4 MPa	13.2	0.7	19.6	2.3	15.6	0.9	15.8	0.8	14.6	1.1	17.2	2.0
55t·h <sup>-1</sup>	12.0 MPa	15.1	0.8	20.2	2.7	19.1	1.6	17.4	0.96	18.5	1.6	20.6	2.4

Remark: Primary air velocity: 20-25 m·s<sup>-1</sup>; grinding force deviation: 0; actual pressure: ≤ 12 MPa

When the coal parameters were basically stable and vane opening was fixed, as the Mill output increased, the grinding force changed automatically at a similar rate, while the coal fineness varied slightly. The coal fineness R90 was basically within the range of 15-20%, suggesting that the grinding force was within the normal range.

## 2.2. Combustion system optimization

**2.2.1. Adjustment and calibration of the tertiary air dampers in individual burners** Given that the FGT was higher at side A than at side B of the boiler, the tertiary air dampers in #1 and #2 burners at each level on side A were increased from 50% to 80% one by one in order to increase the intensity of swirl in the burners there. The FGT at furnace outlet was elevated, the time required to burn the coal powder entering the furnace was shortened, the flame height at side A was lowered. The openings of the tertiary air dampers of #1 and #2 burners at each level were maintained at 50%.

**2.2.2. Recalibration of the full-open positions of secondary air dampers in individual dampers** The internal secondary air was circularly fed into each burner; the internal secondary air and primary air accounted for about 40% of the total air volume. In order to prevent air volume reduction in burners caused by damper blockage or drifting and combustion in oxygen-deficient conditions, the secondary air dampers in all burners were calibrated one by one for the following modes: remote control and local control, mechanical instructions and electric instructions, and external opening and internal opening. The secondary air dampers were adjusted to full-open positions, thus ensuring normal level of uniform distribution of secondary air in all burners. Burner secondary damper easy card astringent, action failure due to slag wear and plug, After each outage of the unit, the need for secondary damper to check to ensure that the damper action flexible, indicating correct.

Optimization of internal and external secondary OFA dampers, central OFA dampers, and air regulators

The central OFA is non-swirling secondary air. The internal and external secondary OFA are both swirling air. The air dampers, located in the upper parts of the upper burners, serve to completely combustion of the remaining coal powder and prevent flue gas disturbance at the furnace outlet. The flow and swirl intensity of OFA can be controlled by regulating the openings of dampers at the OFA ports [7]. Excessively large damper openings can cause oxygen deficiency in the main burners and elevated flame in the furnace, thereby reducing the economic efficiency of the boiler. Table 5 shows the openings of these dampers after adjustments.

**Table 5.** Adjustments to the openings of OFA dampers.

Name	Internal secondary OFA damper(%)		External secondary OFA damper(%)		Central OFA damper(%)		Regulator(%)	
	Before	Now	Before	Now	Before	Now	Before	Now
#1 OFA	20	40	20	40	80	100	50	50
#2 OFA	20	40	20	40	80	100	50	50
#3 OFA	25	40	25	40	80	100	50	50
#4 OFA	25	40	25	40	80	100	50	50
Side OFA	/	/	/	/	80	100	50	50

## 2.3. Adjustments to the openings of secondary air box damper (SABD)

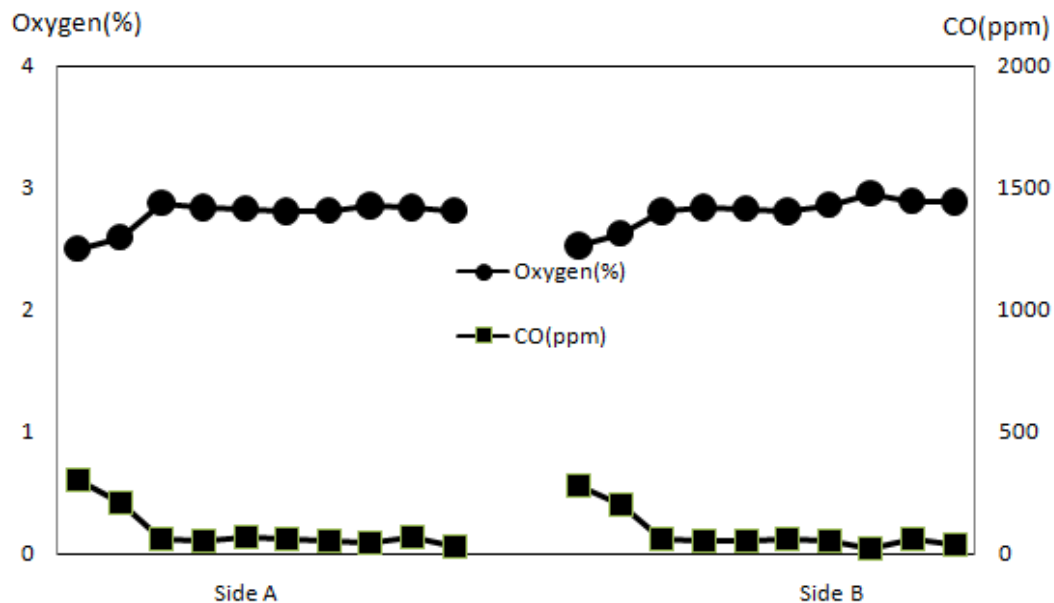
Before adjustments, all SABDs at the three levels had openings of 50%, and the openings of the SABDs for OFA were 10%. To investigate the influence of SABD opening on the tube temperatures of platen superheaters and high temperature superheaters, the openings of the SABDs at the three levels were adjusted to 70% while the openings of the SABDs for OFA remained unchanged.

After the adjustments to the openings of the SABDs, the maximum tube temperature of the platen superheaters decreased from 630° C to 610° C and that of the high temperature superheaters dropped from 625° C to 610° C. The increase in the SABDs' openings increased the oxygen concentration in the main burners, reduced the time required to burn the coal powder in the furnace, and lowered flame height and temperature in the furnace. The tube temperatures of the platen and high temperature superheaters were also lowered.

### 3. Results and discussions

#### 3.1. Distribution of oxygen and CO concentrations in the back end ductwork after adjustments

Figure 1 illustrates the horizontal distributions of oxygen and CO concentrations in the flue gas after the adjustments. The average oxygen concentration along sides A and B was 2.83%. The oxygen concentration was lower in the outermost part than in the central part, but its overall distribution was uniform, indicating that the damper adjustments for the burners did not cause noticeable differential air distribution or combustion. The outer region exhibited slight fluctuation in CO concentration, which was around 300ppm maximum. The average CO level in the back end ductwork was relatively low, at 90.3ppm, suggesting significant improvement in the boiler's combustion efficiency.



**Figure 1.** Horizontal distributions of oxygen and CO concentrations in the flue after optimization

#### 3.2. Distribution of FGT in the back end ductwork after optimization (Table 6)

**Table 6.** FGT Distribution at the inlets of low-temperature superheaters and reheaters.

Active Power	Flue-Gas Temperature of low-temperature superheater ( ° C )		Flue-Gas Temperature of low-temperature reheater ( ° C )	
	Side A	Side B	Side A	Side B
620MW	630	620	627	613
600MW	631	622	625	614
550MW	598	607	596	582
500MW	602	586	601	582
450MW	568	574	571	551
400MW	565	573	579	568
300MW	516	535	535	518

Air distribution in the burners was optimized by adjusting the classifier vanes, Mill output, and grinding forces. After the optimization, the oxygen concentration difference in the back end ductwork was reduced, and the overall CO concentration was substantially lowered despite localized fluctuations. The average CO concentration fell sharply from 400ppm to 90.3ppm; the maximum CO concentration observed in the outer part of the flue decreased from 1500ppm to 300ppm. The FGT

differences under different load conditions were maintained below 30 ° C. In particular, the overtemperature of the heating surface was almost eliminated, and stable operation was achieved when the main and reheat steam temperatures were maintained at the design levels. This significantly increased the economic efficiency of the unit.

#### 4. Conclusions

The mill outlet air velocity was maintained at 20-25 m·s<sup>-1</sup> in the experiments described above. This is because higher air velocities could increase the particle size of pulverized coal and thus inhibit the burning of coal, and too low velocities may cause blockage, which is a threat to the safe operation of mills.

The results of the pulverizing system optimization reveal that the classifier vane opening and grinding force applied by Mill are the major factors affecting the coal fineness. As classifier vane opening increased, the coal fineness decreased and the energy consumption by the mill decreased. When the opening was between 50% and 55%, the coal fineness was largely within the desired range: R90 = 15-20%. As the feeding rate of coal increased, the force applied by the mill increased automatically at a similar rate, thus avoiding the need for manual adjustment.

After the adjustments to the air distribution in the main body of the burners and the secondary air boxes, the oxygen concentrations at sides A and B were nearly the same. The horizontal distributions of oxygen and CO concentrations in the flue became much more uniform. The high temperature superheaters and reheaters exhibited smaller differences in tube temperature, and the FGT differences were kept below 30 ° C under all different conditions.

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