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Application of Non-Fuel Power Generation Technology in Steel Industry

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Abstract: Through continuous equipment technology transformation and full utilization of Ma Steel's abundant gas, the boiler no longer relies on fuel oil for stable combustion during boiler startup, sliding parameter shutdown, and RB, thus achieving safe and stable operation of the boiler under any abnormal working conditions, and achieving good economic and social benefits.
Keywords: fuel oil; excess gas; benefit

Introduction

The 12# boiler of Masteel Thermal Power Plant was designed and constructed based on the blending of 30% (calculated by calorific value) gas. At the beginning of production, due to defects in the gas burner design, the boiler could not meet the design requirements of blending 30% (calculated by calorific value) gas. Approximately 50 tons of fuel oil are still needed each year for boiler start-up, shutdown, and stable combustion, which increases the operating cost of the boiler. The surplus gas of the enterprise cannot be effectively utilized. Since the unit was put into operation, the factory has undergone several technological renovations and ultimately mastered the technology of cold state boiler blast furnace gas ignition and the use of blast furnace gas for unit sliding parameter shutdown [1].

1 Improvement technology of gas burner

1.1 Technical characteristics requirements for gas burners

The burners of gas boilers are roughly divided into natural air supply burners, injection burners, and blast burners according to the air supply method. According to the combustion of different types of gases, the technical requirements and selection of burners also vary. It is necessary to fully consider the capacity range, combustion performance, and regulation performance of the burner [2]. When using blast furnace gas with higher calorific value, a blast furnace burner is generally used, and the air mixes with the gas at a higher speed before entering the furnace for combustion. Table 1 is a classification table for blast type gas burners.

The design of the blast furnace gas burner for the 12# boiler of Masteel Thermal Power Plant uses a diffusion type flame blast furnace gas burner. The advantage of this burner is that it can be arranged at the four corners of the furnace, can burn tangential, and has a longer flame stroke. The disadvantage is that the combustion is unstable during low load operation of the boiler, which cannot meet the requirements of boiler startup and shutdown [3].

1.2 Application of double vortex flow blast furnace gas burner

The dual vortex flow blast furnace gas burner mainly consists of gas channel, air channel, gas nozzle, air nozzle, central pipe, flame detection sleeve and other components. The outer shell of the burner is arranged with a central pipe, a blast furnace gas channel, and a combustion air duct from the inside out [4]. The combustion support pipe of coke oven gas is arranged inside the central pipe; The blast furnace gas pipeline is also equipped with blast furnace gas swirl blades

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Table 1 Classification of blast gas burners

Type	Form of air distribution device		Gas splitter form	
Pipe sleeve type	Cylindrical type		Single tube type multitubular	Circular spray hole Circular seam spray hole Rectangular nozzle
Spiral-flow type	Tangential equation		Central type Peripheral style Center Perimeter Joint	
	Volute type			
	Axial blade type			
	Tangential blade type	Fixed blade		
		Adjustable blade		
Advection type	Cylindrical type		Central type Multi gun type Center Perimeter Joint	
	Venturi tube type			

inside; There are cyclone blades for combustion air (secondary hot air) arranged in the combustion air duct. The swirl direction of the blast furnace gas swirl blade is consistent with that of the combustion supporting hot air swirl blade.

The burner of boiler 12# has a total of 14 layers. The first and second layers (arranged from bottom to top) are blast furnace gas burners. This burner uses coke oven gas as the ignition fuel for boiler start-up, a high-energy ignition gun as the igniter, and is equipped with a pneumatic propulsion device for automatic program control operation [5]. The combustion load capacity of this burner is 17000 m^3/h per unit, the cold length of the burner torch is 3.2 m, the hot length is 3.9 m, the minimum regulated load of the burner is 2000 m^3/h, and it can burn stably.

1.3 Comprehensive utilization of coke oven gas and converter gas

Coke oven gas and converter gas, as by-products of the metallurgical steel industry, have been mainly used by steel mills due to their high low calorific value (coke oven gas 15379-16812 kJ/m3, converter gas 6678-7968 kJ/m^3), followed by power generation and heating. As a thermal power plant in the metallurgical and steel industry, Ma Steel Thermal Power Plant has abolished fuel oil and relied entirely on various types of surplus gas for unit start-up, shutdown, and stable combustion. This can not only save energy and reduce emissions, but also reduce costs and increase efficiency [6]. The 12# boiler in the factory not only utilizes blast furnace gas reasonably, but also continues to effectively utilize coke oven gas and converter gas, especially during low load periods, achieving the ideal effect of stable combustion.

The blending amount of coke oven gas and converter gas is not necessarily better, but is determined based on factors such as furnace temperature, heating surface wall temperature, and main steam and reheat steam temperature [7]. Excessive blending of coke oven gas and converter gas not only causes high furnace temperature and easy coking of water-cooled wall pipes, but also causes overheating of main steam, reducing the service life of pipes. If the blending amount of blast furnace gas is too large, it will further exacerbate the wear of various heating surfaces. Therefore, it is necessary to achieve reasonable blending of coal gas. After several rounds of practice, it was finally determined that the blast furnace gas blending rate was 36000 m^3/h at full load for Boiler 12; The co firing amount of coke oven gas is≤12000 m^3/h; The blending amount of converter gas is≤10000 m^3/h. When the boiler pulverization system is shut down, under the condition of fully burning gas, the blast furnace gas blending rate is≤100000 m^3/h; The co firing amount of coke oven gas is≤18000 m^3/h,; The blending amount of converter gas is≤15000 m^3/h. Table 2 shows the comparison of gas co firing rates between the normal operating conditions of boiler 12# and the shutdown conditions of the pulverization system.

Table 2 Normal operating conditions of boiler 12# and shutdown conditions of the pulverization system (10000 m^3/h)

Name	Blast furnace gas	Coke oven gas	Converter gas
Normal condition	≤6	≤1.2	≤1.0
Shutdown condition of the pulverization system	≤10	≤1.8	≤1.5

2 Gas enhanced combustion technology

2.1 Technical requirements for enhanced combustion of coal gas

Table 3 shows the basic characteristics of blast furnace gas, coke oven gas, and converter gas for boiler 12#.

The calorific value of blast furnace gas is generally about 3372 kJ/m^3, and its theoretical combustion temperature is relatively low, about 1580°C, making it difficult to ignite and stabilize. And blast furnace gas, as the main fuel during boiler start-up, sliding parameter shutdown, and RB, must be

Table 3 Three gas characteristics (dry mass, volume ratio)

Serial Number	Component	Blast furnace	Coke oven	Converter
1	CO/%	24.5	8.6	59
2	CO_2/%	20.4	2.0	18.5
3	H_2/%	1.9	54.46	1.5
4	N_2/%	52.2	3.6	20.6
5	CH_4/%	0.2	23.4	0
6	O_2/%	0.8	1.2	0.6
7	C_2H_4 etc /%	-	2.0	-
8	Qdw/(kJ/m^3)	3372	16538	7887
9	Dust content /(mg/m^3)	10	-	10
10	Mechanical moisture content /(g/m^3)	5	-	5

reinforced with combustion technology at low boiler loads. The main methods adopted include: increasing the temperature of blast furnace gas when it enters the furnace; Ensure the concentration of blast furnace gas to enhance its flame propagation speed; In the adjustment of combustion air distribution between blast furnace gas and air, low oxygen combustion is adopted to maintain a low excess air coefficient; Properly blending coke oven gas or converter gas with higher calorific value; Install a fire protection belt near the nozzle of the blast furnace gas burner to increase the temperature of the ignition area of the blast furnace gas [8].

2.2 Examples of promoting and applying gas enhanced combustion technology

During the initial mixing of blast furnace gas, coke oven gas, and converter gas in the 12# boiler, due to excessive mixing, phenomena such as overheating of the heating surface and tube explosion occurred. After analyzing the furnace heat load data provided by the Provincial Electric Power Research Institute, the technical personnel of the factory finally determined the coal gas blending amount for boiler 12# under different operating conditions. At the same time, the original fifth layer (arranged from bottom to top) ignition oil gun burner will be replaced with auxiliary combustion secondary air; Transform the ninth layer of combustion assisted oil gun burner into a combustion assisted coke oven gas burner. Afterwards, after the combustion assisted coke oven gas (with a single output of 6000 m^3/h) was put into operation at full load, there was a local overheating phenomenon on the heating surface of the boiler. Subsequently, the inlet pipeline of the coke oven gas was modified to ensure that its flow rate into the coke oven gas burner was≤4000 m^3/h, and the phenomenon of overheating on some heating surfaces of the boiler was eliminated. Figures 1 and 2 show the modification of the inlet diameter of the coke oven gas and the pictures of the coke oven gas burner, respectively [9].

In order to improve the ignition ability of blast furnace gas in the early ignition stage of the boiler, the 12# boiler



Figure 1 Coke oven gas pipeline renovation



Figure 2 Transformation of coke oven gas burner

underwent denitrification transformation in 2015. At the same time, a flame retardant belt was laid near the blast furnace gas burner to reduce the impact of water-cooled walls on gas ignition, increase the temperature of the gas ignition area, and facilitate the ignition and combustion of low calorific value blast furnace gas.

At the same time, it also meets the needs of boiler staged combustion and reduces nitrogen oxide emissions. During the low load period of the boiler, while blending blast furnace gas, furnace 12# can also blend converter gas with blast furnace gas of≤10000 m^3/h. Due to the low calorific value of converter gas between 6678 and 7968 kJ/m^3, it

better promotes the combustion of blast furnace gas and meets the stable combustion requirements of the boiler during the low load period.

3 Conclusion

Most conventional power plants use plasma generators to achieve fuel free power generation, while metallurgical and steel enterprise power plants can also achieve fuel free power generation through comprehensive utilization of gas. China is the world's largest producer of steel, and many steel plants have their own power plants. How to effectively and comprehensively utilize surplus gas is a compulsory course for every steel plant. This not only meets the policy requirements of national energy and environmental protection comprehensive utilization, but also reduces the cost of steel per ton for steel enterprises, improves economic benefits, and is the only way for steel enterprises to pursue circular development.

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