The Numerical Simulation and Experimental Research on Combustion Process in 660MW Boiler

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Abstract. In order to solve the problems of thermal insulation and ash prevention of the furnace combustion layer temperature detection devices installed on the boiler furnace, FLUENT software is used to numerically simulate the actual combustion process in the furnace of 660 MW power plant boiler, and the combustion status of each layer in the furnace is analyzed and studied. And then, according to the results of data simulation the thermal insulation and ash prevention technology implementation of the furnace combustion temperature detection devices is guided. The installation operation test results show that the furnace combustion temperature detection devices work within the range of instrument allowed -20°C~85°C temperature, which can obtain the direct, rapid, real-time furnace combustion temperature data that provides a valuable source of data for further optimization control of boiler combustion process.

1. Introduction
The combustion state in the furnace of a power plant boiler affects the boiler output, thermal efficiency and equipment life. At present, the rough operation mode of power plant boiler may cause local high temperature in furnace, coking, tube blasting, uncertainty of pollutant emission concentration and fire extinguishing in furnace, and local high temperature may accelerate sulfur corrosion. An important measurement problem in the combustion of power station boiler is the measurement of furnace temperature field, which is the most direct reflection of the stability of furnace combustion state. Through the accurate measurement of it, the judgment, prediction and diagnosis of the combustion state of the boiler can be realized, and the reasonable and sufficient combustion of the fuel in the furnace can be controlled to ensure the uniform distribution of the temperature field in the furnace[1-6]. In order to solve the problem of directly measuring the temperature of the combustion layer in the boiler chamber, a set of temperature monitoring system of the combustion layer in the boiler chamber was installed and operated by drilling holes in the boiler chamber through analyzing the structure characteristics of the water cooling wall of the boiler and the combustion condition of pulverized coal in the furnace. Because of the high temperature in the hearth, in order to prevent burning temperature detection device and front plug temperature detection device, to solve the problem of boiler furnace combustion process is simulated, for in the combustion chamber of a stove or furnace temperature detection device on site installation for reference, and then reference the results of numerical simulation, the design of furnace temperature detection device on insulation dust prevention measures, and on site installation to test its practical operation effect.
2. Numerical simulation of boiler furnace combustion process

2.1. Introduction to boiler
The numerical simulation object is a coal-fired boiler for a 660MW supercritical unit of a power plant. The combustion equipment system of the boiler is arranged in front/rear wall type, and the burner system is offset and swirling. After the air flow from the pulverized coal burner and the exhaust air nozzle enters the furnace, each burner forms a separate flame in the furnace. The front/back walls of the boiler are each equipped with 3 layers of burners, and 4 burners in each layer. The burning layers corresponding to the fixed end and expansion end of the boiler are named as layer A, layer B, layer C, layer D, layer E and layer F from top to bottom, and there are altogether 6 layers. There are 6 infrared temperature probes, which are installed in the 6 combustion layers of the fixed end and extension end of the boiler respectively.

2.2. Grid division and mathematical model selection
Considering that the flow and reaction process parameters in the region near the burner change significantly, the furnace is meshed in the region near the burner. Above and below the burner area furnace, the mesh size will gradually enlarge, to achieve a smooth transition of the mesh size. The mesh types are mainly tetrahedral pyramid and wedge, and the number of meshes is about 120,000. Numerical simulation of the gas phase turbulent model is with cyclone modified Realizable k-ε model in combination with Standard Wall Function combined with quantities inside the furnace Wall, on the part of the near Wall to calculate. The radiation heat transfer inside the boiler is described by p-1 model. The way for pulverized coal particles to enter the boiler from the primary air duct is surface, and the velocity is the primary wind speed. The particle size distribution of pulverized coal particles meets Rosin-Rammelr formula[7-10].

2.3. Numerical simulation results and analysis
The temperature distribution diagram of the longitudinal section of the burner in the numerical simulation boiler under the operating condition of full load is shown in figure 1.

![Figure 1. Distribution of temperature field in longitudinal section of boiler burner.](image)

As can be seen from figure 1, under the operating condition of the boiler at full load, the distribution of temperature field in the boiler is axisymmetric. The high temperature zone in the furnace is located in the upper part of the boiler burner slightly above the position. The highest temperature is about 2160K (about 1886℃). From the upper part of the burner successively downward, the temperature in the furnace gradually decreases, while the temperature in the lowest part of the burner above the area gradually increases. On both sides of the backflow area of the burner, the maximum temperature of pulverized coal combustion in the whole furnace is 2160K (about 1886℃) because the pulverized coal starts to burn at a high temperature and the temperature in the center of the backflow area is low.
As can be seen from the distribution of carbon concentration in the longitudinal section of the boiler burner in figure 2, the temperature near the water wall of the furnace is up to 1630K, and there is a small amount of pulverized coal. The water wall around the burner is directly washed by the airflow with pulverized coal, and the temperature is higher, which may lead to slagging.

3. On-site installation and operation of temperature monitoring system of combustion layer in furnace

3.1. Furnace combustion layer temperature monitoring system
According to the numerical simulation analysis, it is understood that the temperature field distribution in the furnace is axisymmetric. The upper layer has the highest temperature, and the temperature in the highest temperature zone under the operating condition of full load is 2160K. The temperature of the water cooling wall is also over 1000 ℃, which makes it easy to slag the water cooling wall. Therefore, the heat insulation and ash blowing should be considered in the installation and design of furnace combustion layer temperature monitoring system, and corresponding heat insulation protection and ash blowing measures should be taken. Through comprehensive analysis, research and design, the r&d team developed a set of furnace combustion layer temperature monitoring system, which was mainly composed of the boiler side temperature detection device and the electronic side monitoring device. The boiler temperature detection device is mainly composed of infrared temperature probe, signal processor, heat insulation protection device, cooling device and filter, etc., among which, heat insulation protection device is used to play the role of heat insulation, protect the infrared temperature probe from being burned, so that it can work in the allowable instrument temperature environment. Cooling filter device is used to play the role of blowing dust, prevent the infrared temperature probe front end by dust pollution.

3.2. System operation results and analysis
The temperature monitoring system of the combustion layer in the furnace was started to operate, and the real-time temperature curve of the infrared temperature probe installed on the boiler side was obtained through the monitoring cabinet in the electronic room of the power plant, as shown in figure 3 below.

Figure 2. Carbon concentration distribution in longitudinal section of boiler burner.
Figure 3. Temperature variation curve of A/B/C three-layer infrared probe instrument at the fixed end of the furnace in a certain period of time.

As can be seen from figure 3, the temperature of the infrared temperature probes on layers A, B and C at the fixed end of the boiler are all within the range of -20℃~85℃ allowed by the equipment, indicating that the thermal insulation protection measures of the temperature detection device are effective.

Figure 4. Temperature change curve of three layers A/B/C at the fixed end of the furnace when the unit is loaded with 390MW.

Figure 4 shows the furnace temperature of a certain period measured by the temperature detection device on layers A, B and C of the furnace combustion layer when the unit is under a 390MW load. The measurement period is set to 1min, and the average temperature of layer A, layer B and layer C in the furnace is 1155℃, 1340℃ and 1498℃ respectively calculated according to the average time. It can be seen that with the increase of the combustion layer in the furnace, the temperature of the furnace layer also increases gradually, and the temperature of the combustion layer on the top of the furnace is the highest. This result is consistent with the analysis conclusion of numerical simulation. And it can also be seen that the temperature detection device works normally without the problem of the front plug of the probe, which indicates that the anti-ash measures adopted for the temperature detection device are effective.

4. conclusion

Through the numerical simulation of the combustion process of boiler furnace, the distribution of temperature field in the furnace and the problem of easy slagging are analyzed and studied in advance, which provides a reference for the actual installation of temperature detection device in the furnace. Before the temperature detection device is installed in the furnace, heat insulation and ash blowing protection technologies are carried out on the temperature detection device in advance. The actual
installation test results show that the thermal insulation and ash prevention technology adopted by the temperature detection device is effective, which can ensure that the temperature detection device on the furnace works within the temperature range allowed by the instrument and prevents the temperature detection device near the furnace from being burned due to excessive temperature, thus resulting in the failure of normal detection of the furnace temperature.

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