Preliminary Study on Application of Infrared Thermal Imaging Technology in Combustion Control of Coal-fired Boilers

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Abstract. The principle of infrared thermal imaging is briefly described. According to the actual situation of the boiler and the investment cost, the location and quantity of the infrared cameras are analyzed, it is reasonable to set up an infrared camera on both sides of the end of the boiler grate for combustion monitoring. In addition, the thermal image of coal combustion in the boiler furnace monitored by the infrared cameras are analyzed and researched. It is concluded that the infrared thermal imaging technology can be applied to the combustion monitoring of coal-fired boilers, which is beneficial to saving coal, energy saving and environmental protection.

1. Introduction
Coal accounts for more than half of Chinese energy consumption. In 2018, Chinese coal consumption accounted for 59.0% of total energy consumption, and 57.7% in 2019. Although China has formulated corresponding policies to encourage the use of other clean energy sources, coal consumption will still occupy a dominant position in Chinese energy consumption structure for a considerable period of time in the future. The burning of coal is recognized by the world as the main factor of atmospheric pollution. In our country, the heating source mainly relies on coal-fired boilers to burn raw coal. Every heating season, the continuous occurrence of haze weather in northern cities makes people experience the harm caused by coal burning. Therefore, reducing coal consumption is one of our country’s important measures to solve current environmental problems.

Improving the efficiency of coal-fired boilers is an important means to reduce coal consumption. The combustion of coal in the furnace directly determines the consumption of coal-fired boilers. If the burn-out section in the furnace is too long, the blast volume was too large, the furnace temperature was uneven, and the combustion efficiency was low, resulting in an increase in the amount of coal burned; if the burn-out section is too short, the coal cannot be burned completely, which also leads to an increase in the amount of coal burned. The current boiler combustion control mainly monitors the combustion of the boiler by measuring the furnace temperature, exhaust gas temperature, furnace pressure, oxygen content and other parameters, and then manually adjusting the blast volume, induced air volume, and fuel filling volume according to the measured parameters. If you want to understand the actual situation of coal combustion, you can only use the personnel to watch the combustion status of the coal in the furnace through the fire hole on the boiler regularly, which does not reflect the combustion status of the coal in a timely manner. In the combustion control process of the boiler, there is a lack of visualization of fuel combustion in the furnace. Using infrared thermal imaging technology, the coal combustion in the furnace is transmitted to the computer screen in the control room in real-time in the form of images, allowing managers to observe the combustion in the furnace at any time, so that they can make
corresponding adjustments in time. Not only can the efficiency of the boiler be improved, and the consumption of coal be reduced; the operation of other facilities in the furnace can also be observed to facilitate detection of hidden dangers and corresponding countermeasures[1-5].

2. Infrared thermal imaging technology is applied to monitoring the combustion status of coal-fired boilers

Infrared thermal imaging technology is applied to collecting the energy radiated by the measured object through an optical lens, gather it on an infrared detector by a scanner, and then convert it into a signal, which is amplified and processed, and outputs electrons that can reflect the surface temperature field of the measured object. The video signal is displayed on the monitor in pseudo-color form and becomes the thermal image that we see. Due to the imaging principle of infrared thermal imaging technology, it has the characteristics of non-contact temperature measurement, large measurement temperature range, and ability to display the temperature field of the measured object. The temperature in the boiler furnace is high, and other temperature measurement equipment cannot directly measure its temperature. Infrared thermal imaging technology is a non-contact temperature measurement method, which can more intuitively see the combustion status and temperature distribution in the furnace [6-9].

2.1 Principle of infrared thermal imaging

The principle of infrared thermal imaging is to use photoelectric technology to detect the infrared specific waveband signal of the object's thermal radiation, and convert the signal into graphics and images that can be visually distinguished by humans. As long as the surface temperature of an object exceeds absolute zero (−273 °C), electromagnetic waves will be radiated. As the temperature changes, the radiation intensity and wavelength distribution characteristics of electromagnetic waves will also change. Electromagnetic waves with wavelengths between 0.75 μm and 1000 μm are called "infrared rays". The wavelength of "visible light" is between 0.4 μm and 0.75 μm. Therefore, the human eye must use infrared thermal imaging equipment to see the infrared thermal image. Due to the extremely poor penetration of infrared rays for most solid and liquid, infrared thermal imaging detection is mainly based on measuring the infrared radiation energy on the surface of the object. In addition, because infrared rays radiate in the air, they will be absorbed by atmospheric constituents (especially H2O, CO2, CH4, N2O, O3, etc.), and the intensity will decrease significantly, only in the two bands of short wave 3 μm−5 μm and long wave 8~12 μm (Usually called the atmospheric window) has a good penetration rate, so most infrared thermal imaging equipment mainly detects these two bands, and forms a thermal image that can be recognized by the human eye, at the same time calculates and displays the object’s surface temperature distribution. Due to the above principles of infrared thermal imaging, it has the characteristics of wide measurement range, non-contact temperature measurement, fast response speed, and intuitive measurement results. Therefore, infrared thermal imaging technology is widely used in military, medical and health, industrial production, chemical industry, electric power, Construction and other fields [10-12].

2.2 Using infrared thermal imaging technology to monitor the combustion status of coal-fired boilers

Coal-fired boilers are widely used in the heating industry in northern our country, and better monitoring of the combustion of coal in the furnace is an important prerequisite for saving coal. At present, to know the combustion of coal in the furnace, it is still observed by human eyes through the fire hole, which cannot reflect the combustion status of coal in real time; The temperature in the furnace of a coal-fired boiler is about 1200° C, and ordinary temperature measuring elements cannot withstand such a high temperature, and even if they can be measured, they are easily damaged. Infrared temperature measurement is a non-contact temperature measurement method. In theory, it has no upper limit for temperature measurement. Currently, it can measure high temperatures between 6000° C and 7000° C. Therefore, the application of infrared thermal imaging technology to monitor the combustion
situation in the furnace of a coal-fired boiler can not only directly view the thermal image in the furnace, but also know the temperature distribution in the furnace at any time.

Setting the location and quantity of infrared cameras directly determines the quality of thermal image collection and the initial investment. In Figure 1, one infrared camera is installed at the front, middle and rear of each side of the boiler furnace, with a total of 6 infrared cameras. Under the premise of satisfying boiler combustion control, the fewer infrared cameras are installed, the less investment. The more fully the coal is burned in the boiler, the better the boiler's emissions, and the less fuel is wasted. At the end of the boiler grate, it should be the cinder remaining after the coal combustion is completed. Use an infrared camera to monitor the combustion of the coal at the end of the grate, and you can directly see whether the coal has been completely burned, so that the boiler combustion can be controlled according to the monitored situation. Therefore, the best placement of the infrared cameras should be at the end of the boiler furnace, on both sides of the burnout section at the end of the grate. After many experiments, it is reasonable to set up an infrared camera on both sides of the end of the boiler furnace, which can clearly see the combustion of coal on both sides of the grate; if only one infrared camera is installed on one side, and there is burning coal in the middle of the grate, the thermal image collected will not be able to see the actual combustion of the coal on the other side due to the flame blocking, which will cause errors. judgment. Therefore, combining investment and monitoring effects, it is best to install an infrared camera on both sides of the boiler grate for combustion monitoring.

![Figure 1. Infrared cameras layout drawing](image)

The following are some infrared thermal images in the furnace of coal-fired boiler.

Figure 2 and Figure 3 are infrared thermal images of the burnout section of a chain grate coal-fired boiler. The dark area in the images have lower temperature, which are the burned coal cinder, and the brighter area have higher temperature, which are the burning coal. From these two infrared thermal images, we can see the combustion situation in the furnace of the boiler, at this time: the coal on the grate near the observation point has been burned and the lower temperature cinder remains, and the coal on the grate opposite the observation point is burning, this part of the unburned coal will be discharged into the cinder pool along with the rotation of the grate and wasted. From the infrared thermal images, not only the combustion status of coal can be seen, but the status of other facilities in the furnace can also be seen, the dark-colored vertical strips in the upper left of image 1 are the water-cooled wall tubes of the boiler, the uniform color proves that they are in good condition.
Figure 2. Thermal image of the rear of the furnace 1

Figure 3. Thermal image of the rear of the furnace 2

Figure 4 and Figure 5 show the combustion of coal in the front of the boiler. The bright part in the upper part of the two images are the flame, this part is the highest temperature area in the furnace, the temperature is about 1200 °C. The darker part in the lower part of the two images are the burning coal bed, and the temperature is also around 700° C

Figure 4. Thermal image of the front of the furnace 1
Figures 6 and 7 show the combustion of coal in the middle of the boiler. The bright part in the picture is the flame formed by the burning coal on the grate, and the temperature is also above 1000°C. In the images, the water-cooled wall tubes of the boilers arranged vertically in strips are also clearly visible, and the colors are uniform, which proves that they are in good working condition.
From the actual observations above, the use of infrared thermal imaging technology can not only monitor the combustion situation of the boiler, but also monitor the operation of other boiler facilities to predict accidents and reduce losses.

3. Conclusion
Infrared thermal imaging technology used for combustion control of coal-fired boilers can not only directly view the infrared thermal images in the furnace, but also know the temperature distribution in the furnace at any time; at the same time, it can also monitor the operation of other facilities in the boilers, to predict the accidents in order to make corresponding countermeasures to reduce losses. The application of infrared thermal imaging technology to the combustion monitoring of coal-fired boilers is conducive to saving coal, energy saving and environmental protection.

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References
[1] Zhang Qing, Li Guang, Zuo Xiaoyan, Dai Jiyu. Journal of Xinjiang Petroleum Institute, 14(2002)
[2] Chen Zhigang. Electronic Measurement Technology, 35(2012)
[3] Xu Mingjiang, Yang Zhaojian. Guangzhou Architecture, (2002)
[4] He Ziqi. Bulletin of Science and Technology, 29(2013)
[5] FAN C L, SUN F R, YANG L. Proc of the Joint 30th Int Conf on Infrared and Millimeter, (2005)
[6] REINHARDT W W. . ASNT Fall Conf and Quality Testing Show, (1994)
[7] Inagaki T, Iwamoto T. NDT&E International, 32 (1999)
[8] Hanjalic K, Kenjeres S. Wind Eng. Ind. 96(2008)
[9] DONG JO YANG, CHANG HYUN KIM, International Journal of Modern Physics B, 17( 2003)
[10] N. P. Avdelidis, A. Moropoulou. Energy and Buildings, 35(2003)
[11] D.Defer, J.shen, S.Lassue, etal. Energy and buildings, 34(2002)
[12] Akira Hoyano, Kohichi Asano, Takehisa Kanamaru. Atmospheric Environment, 33 (1999)