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Visualization Measurement of the Flame Temperature in a Power Station Using the Colorimetric method

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Abstract: This paper presents a study on the measurement of the temperature distribution in a power station based on an optical flame/temperature visualization system. This system operates upon the colorimetric principle combining advanced optical sensing and digital image processing techniques. The system was calibrated using a blackbody furnace as standard temperature source. Experimental results are obtained from a 300MW power station boiler. As the measurement height changed, the temperature captured by the system also changed. The maximum temperature occurs on the upper level of the burners. The temperature decreased when the load went down and tended to be stable when the load remained steady. Experimental results also reveal that this system is capable of online measurements of the temperature distribution in a combustion zone. This system can potentially be applied to many areas such as power generation, metallurgy or chemical engineering.

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Keywords: combustion, Colorimetric method, temperature, load

1. INTRODUCTION

Optimal operating conditions are required to achieve increased combustion efficiency and reduced pollutant emissions. One of the most effective means is to characterize the flame since the flame is the central reaction zone of combustion process. With the advent of optical sensing, image processing and computing techniques, a number of studies have been carried out on the monitoring and characterization of flames [1-4]. The two-color method [5-7] based on the flame radiation principle have the advantages of simple operation, quick response, thus having wide applications on the flame measurement.

This paper is concerned of an intelligent vision system for the monitoring of combustion flames by combining optical sensing and digital image processing technique. For this system, an image of a flame is split into three monochromatic images by the light splitter assembly. The wavelength and bandwidth are chosen mainly according to the intensity of the light radiation from a flame. Using blackbody furnace as the standard radiant heat source, post-processing of the grey levels of the CCD images yields the relationship between radiant temperatures of the flames and the grey levels of the CCD images in each band of wavelength. The mesurement priciple show in references [6,7].

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2. THE ACTUAL MEASUREMENT AND ANALYSIS

This system is applied on the No.3 boiler of a power station located in Hebei province, China. The B&WB-1025/18.3-M type boiler which uses the 'front and back wall opposed firing method' was manufactured by Babcock & Wilcox Company LTD.

Fig.1 shows the schematic diagram of the combustion monitoring system. The flame monitoring system consists of an endoscope, an optical assembly, a CCD camera, a frame grabber and image processing software and the auxiliary water/air devices for cooling and keeps clean of the endoscope.

The experiment was mostly carried out at corner B of the boiler, the inspection holes of each level were regarded as observation points. Fig 2 shows the flame image and temperature distribution. The average temperature obtained by both of the optical system and Raytek thermal radiation thermometer is compared. According to the comparison the temperature difference increased as the temperature went up. The absolute error is not more than 25℃ and the relative error is below 2%. Experimental results obtained indicate that the system is capable of online measurement of the temperature distribution of the flame field.

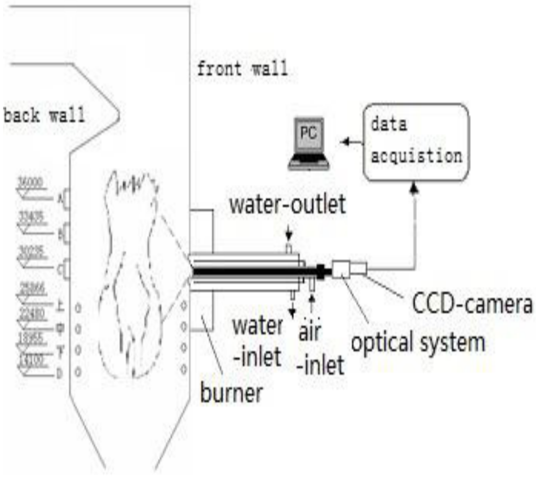

Figure1 boiler and measuring system

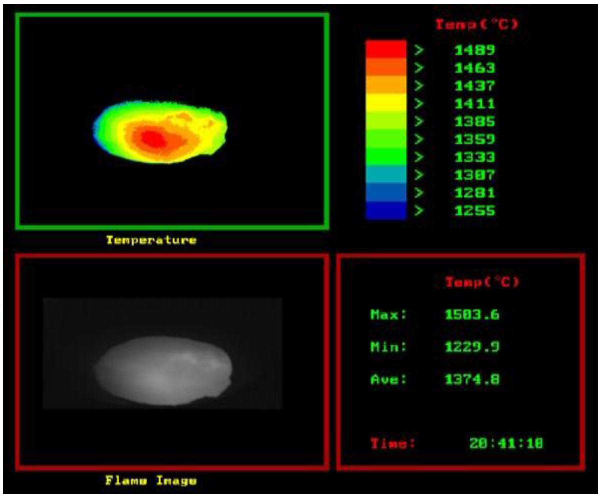

Fig2 flame image and temperature distribution of the upper burner

2.1 The relationship between the flame temperature and furnace height

The data in figure 3 shows the average temperatures at different levels. The minimum average temperature occurs at level D and then increase to the maximum is encountered at the upper-level and then decrease to level A. The temperature curve of Fig.3 reveals a typical temperature distribution, temperature peaks at the mid-level. The temperature distributions at the front wall and back wall present the same trend. Moreover, the transient state is also monitored by this system. If this system is focused on a certain part of the boiler, for example, a coking condition will be detected by combining the online monitoring result with the temperature distribution and image information.

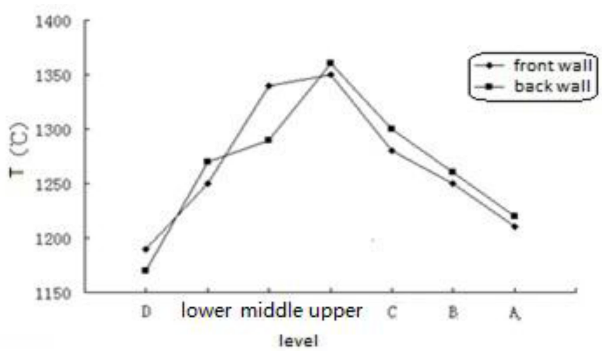

Fig3 Simultaneous average temperature at each level

2.2 The relationship between combustion temperature and load

The experiment has been carried out at the inspection hole of level C at the front wall of the boiler. Flame information has been obtained by data acquisition and an image acquisition process. Level C is chosen as the experimental target for the three reasons: Firstly, level C is above the upper-burners. The distance between level C and the upper burners is about 4m. The temperature of the flame remains highest at this height. Secondly, pulverized coal will be mixed quickly after it is injected into the boiler and disturbed in the region of the burners, so there is little disturbance. The temperature will be more stable. Thirdly, the temperature of level C can reflect the general combustion inside the boiler.

The actual measurement tested the relationship of combustion temperature and load. The average load reduction rate showed in table 1 is 3MW/min, the continuous load reduction value is about 10-20MW. The unit remained in steady operation for a short time after the load changed and then kept on reducing. Finally the load dropped from 306MW to 203MW and the reduction is 34%.

Table1 load of the unit

item	22:00	22:30	22:44	23:15	23:30	0:10	0:45	1:15	1:30	1:45
Load (MW)	306	290	268	260	253	234	224	204	204	203
burner number	20	16	16	16	16	14	12	12	12	12

Digital images were collected and pretreated through image processing. As the unit load reduced, the temperature also went down. The average temperature dropped from 1370℃ at full load (306MW) to 1160℃ when the load was 203MW. The drop of the average temperature is more than 200℃. The maximum temperature also indicated the same trend but had a larger drop. Fig 4 shows the average and maximum temperature changes during the reduction process (from 306-209MW, 224-204MW). Images were captured every 10minutes.

As Fig 4 and Fig 5 demonstrate, as the unit load is reduced the temperature fluctuated within a large range. The curves show that the temperature went down as the load reduced. The temperature remained steady when the load was stable. The maximum temperature varied within a larger range than average temperature during the reduction process and the steady operation. In contrast to the maximum temperature, the average temperature can better reflect the change of the combustion generated inside the

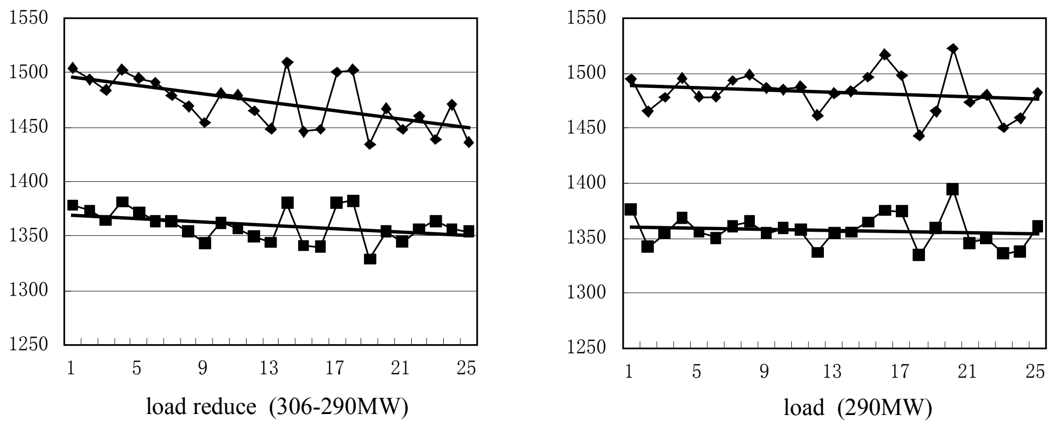

Fig4 Load reduction at high level

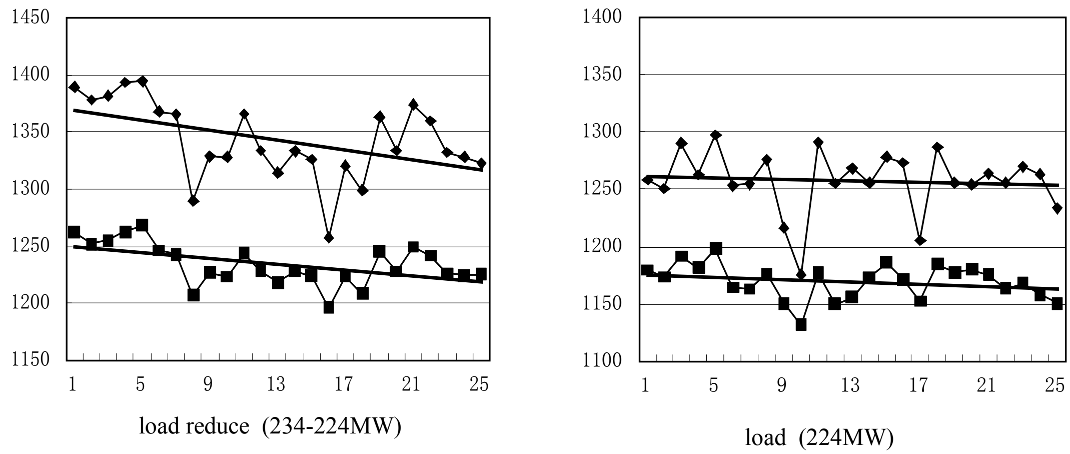

Fig5 Load reduction at low level

furnace when load of the unit was high (shown in Fig 4) than when the load is low (shown in Fig 5) . Therefore taking the average temperature, together with other known information, it will provide abundant data for combustion diagnosis. There is another conclusion obtained from analyzing the data, which is that the fluctuation of the temperature is reduced as unit load goes down.

3. CONCLUSION

Instrumentation based on an optical system for the instantaneous measurements of the combustion/temperature distribution has been described and discussed. This system was tested in a power station boiler. Experimental results indicate that the combustion temperature and combustion process are closely interrelated. Output of the combustion temperature can reflect the change of the combustion occuring inside the furnace. The maximum, minimum and average temperature obtained by the system has been discussed. It has been concluded that the maximum temperature represents the instantaneous status of the combustion and the average temperature can clearly reflect the trend of the variations of the combustion

References

[1] Y.Huang，Y.Yan，G.Riley. Vision-based measurement of temperature distribution in a 500-kW model furnace using the two-colour method. Measurement [J]28 (2000)175-183.

[2] Teri Snow Draper, Darrel Zeltner, Dale R.Tree, et al. Two-dimensional flame temperature and emissivity measurements of pulverized oxy-coal flames. Applied Energy 95(2012)38-44.

[3] Sun Yipeng, Lou Chun, Zhou Huaichun. A simple judgment method of gray property of flames based on spectral analysis and the two-color method for measurements of temperatures and emissivity. Proceeding of the Comubstion Institute 33(2011) 735-741.

[4] Cai Xiaoshu, Ji Kun, Su Mingxu, Zhao Zhijun. The study of pulverized coal combustion diagnosis and flame criterion based on the spectrum analysis. Proceedings of the CSEE [J]. vol.24(1), pp211-215,2004.

[5] D.Hernandez, J.L.Sans, et al. Experimental validation of a pyroreflectometric method to determine the true temperature on opaque surface without hampering reflections. Mesaurement 42(2009) 836-843.

[6] Zhihong Li, Shi Liu, Huaiping Mu, et al. Calibration and Experimental Research of a Multiple-wavelength Flame Temperature Instrumentation System. J. of Thermal Science Vol.13, No.4, 2004, 371-375.

[7] Zhi-Wei Jiang, Zi-Xue Luo, Huai-Chun Zhou. A simple measurement method of temperature and emissivity of coal-fired flames from visible radiation image and its application in a CFB boiler furance. Fuel 88(2009) 980-987