

Study on Combustion Characteristics of Pulverized Coal Based on Instantaneous Two-dimensional Measurement

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Abstract: The purpose of this paper is to compare the releasing characteristics of the flame intermediate OH when the pulverized coal from Zhundong region and the acidified treated pulverized coal are completely burned at constant temperature. Since the content of the H in the complete combustion intermediate product OH is corresponding to the content of the H element in the pulverized coal, and then it can be used to compare the changes of the H content in Pulverized Coal after pickling. An open-type burner is fabricated to apply optical measurement techniques. In this paper, simultaneous measurement of OH-planar laser-induced fluorescence (PLIF) is performed and the entire main combustion area is examined. It is found that the content of OH in the acidified treated pulverized coal is generally lower (compared with the raw coal), which is consistent with the results of the pulverized coal ultimate analysis. Meanwhile, it is found that the burning range of the whole pickled coal flame becomes smaller and that the peak value of the coal powder after pickling is slightly delayed.

1. Introduction

Coal is an important and promising energy resource for electricity supply because its reserve is far more abundant than those of fossil fuels, especially in China[1, 2]. An amount of coal storage was found in the zhundong region (in the east of Junggar Basin) of China. According to China's annual production of coal, a zhundong coal field is enough for the whole country to use for a hundred year[3], so the study of the zhundong coal is very important. The zhundong coal's alkali metal content is high, especially the content of Na is relatively high, which can cause serious pollution[4]. Sodium salt is volatile substance, which volatiles at high temperatures and is easy to condense in the heating surface to form sintered or cohesive ash deposition, but pickling treatment can remove most of the alkali metal elements such as sodium[5-7]. In this study, planar laser-induced fluorescence[8, 9] is combined with a laboratory-scale pulverized-coal combustion burner. Spatial relationship of the combustion reaction zone and the relative content of the mid products OH of the flame is detected,

and it is investigated by simultaneous measurement of OH-PLIF[10, 11]. The intensity profiles of OH-PLIF are analysed by statistical methods.

2. Experiment Apparatus and Arrangements

2.1 Pulverized-coal combustion burner

The turbulence pulverized-coal combustion burner is fabricated as an open-type apparatus to apply various optical measurement techniques. The burner and the supplying system are illustrated in Fig.1. The burner is a tapered burner and the inlet gas of the burner is the premixed methane with air, and the outlet is a round-shaped combustion plate made of high-temperature iron-nickel alloy. The diameter of the combustion plate is 60 μ m. The mixed gas can pass smoothly through the combustion plate. The external part is made of closed ring refractory material, so the mixed gas in the upper part of the burner achieves a buffering effect to avoid blowing pulverized coal directly. The main air for combustion and the combustion-supporting methane is supplied from a compressor and the flow rate is regulated by a screw controller. Coal particles with a diameter of 75 μ m are placed on the combustion plate, controlling the flow rate of the mixed gas to make the pulverized coal in a semi-suspended state so that the gas is in full contact with the gas. The coal used in this experiment is zhundong coal.

The acidified pulverized coal is treated on the basis of the coal. Table 1 shows the ultimate analysis of two pulverized-coal. In this study, the mixture of methane and air passes through the combustion plate. In one aspect, it achieves the effect of combustion-supporting, because the mass of coal is small and flame stabilization is impossible for pure pulverized-coal flame. In another aspect, it ensures the pulverized coal in sufficient contact with the pulverized coal particles to ensure full combustion. The exhausted gas is released into the atmosphere by a ventilator after cooling.

The diameter of Zhundong pulverized coal is 75 μ m-20 μ m. The weight of coal samples used is 2.000g (\pm 0.0010g), and it was put into triangular conical flask. Next, 150 mL ultrapure water was added with the rotor and then the conical flask was sealed with a sealing film. The mixture was stirred at 20 °C for 12 hours. The mixture was filtered through a solvent filter and the residue was washed. The residue was transferred to 1 mol/L of a 150 mL HCl solution for 12 hours and then filtered, washed and dried.

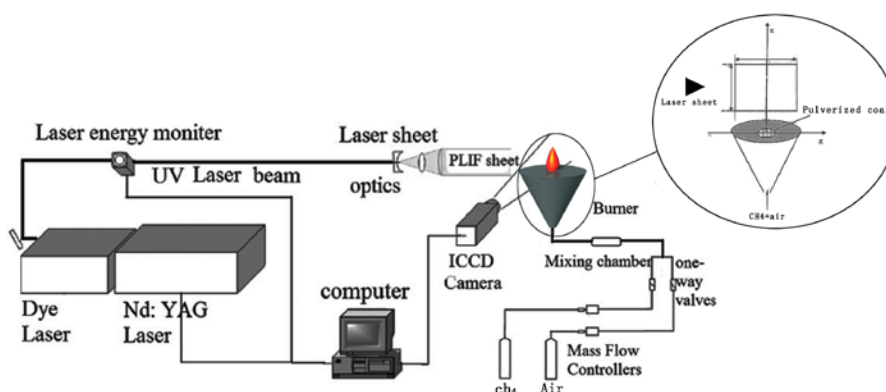


Figure. 1

2.2 Optical measurement system

In the study, PLIF is applied to pulverized-coal flame, and the detailed combustion characteristic of devolatilization is examined. Furthermore, the spatial relationship of the combustion reaction zone is investigated. The simultaneous measurement system for OH-PLIF is shown in Fig.1.

Table 1 Ultimate analysis

Coal sample	Carbon	Hydrogen	Nitrogen	Total sulfur
raw coal	66.20	3.67	0.64	0.62
Acidified coal	65.62	3.27	1.03	0.45

A ND: YAG pulse laser (spectra-physics) is used as the light source of the laser sheet. For the OH-PLIF, the P1(8) absorption line of the (1,0) band is excited using a wavelength-tunable laser () pumped by the third-harmonic wave of the ND: YAG pulse laser. Laser-induced OH fluorescence, on the one hand, is passed through an optical hand-pass interfere filter with a transmission peak wavelength of 320nm and a half-value width of 20nm and is captured by a CCD camera () coupled with an image intensifier. TTL signal generated by two pulse delay generators are used for timing control of the ND: YAG pulse laser and image capture of the OH-PLIF. In the measurement of OH-PLIF, the Rayleigh scattering image of air is measured, and the correction of laser intensity distribution along the axis direction is performed.

2.3 Experimental methods and conditions

In the experiment, first of all, the gas flame, where air and methane are supplied to the combustion plate. After 12 minutes, the temperature of the combustion plate was measured with a thermocouple about 800 degrees centigrade. Because the mass of the pulverized coal is less, the combustion time is short, and the combustion is completed within 12s during the test, so the temperature on the combustion plate can be regarded as a constant value. Table 2 shows the experimental conditions. Open the laser in advance, in this measurement, the excited of OH-PLIF fluorescence was obtained using a 10HZ ND: YAG laser with power of 250mJ per pulse and a pulse time of 10ns. LIF signals of OH emission at wavelength around 283.286nm were detected by intensified relay optics and a CCD camera equipped with a UV lens and an OH filter. 120 images are used for each specified case, with all OH-PLIF images corrected by subtracting the background images from the experimental images data, along with intensity correction through the energy monitor. When the mixture gas reaches 800 degrees centigrade in 12 minutes, the pulverized coal is arranged on the combustion plate, and then the OH in the pulverized coal is measured. In this study, the pulverized-coal flame is of the open type, and it is considered that the excess air coefficient is not important, because not only the mixed gas contains air, but also the combustion by entrainment of ambient air occurs. The airflow rate is determined to avoid the deposition of the coal particles on the combustion plate. The choosed methane flow rate is the minimum amount to form a stable flame. Fig. 1 shows the measurement and data processing area, where the axial and radial distances are shown in zone z and zone x respectively.

Table 2 Experimental conditions

Quality of pulverized coal	1.5g
Air flow rate	$2.17 \times 10^{-5} \text{m}^3/\text{s}$
CH4 flow rate	$2.44 \times 10^{-4} \text{m}^3/\text{s}$
Thermal input of CH4	4.39kw

3. Results and Discussion

3.1 Total amount of OH in combustion process

In order to compare the total amount of OH in the acidification treated coal and raw coal in the entire combustion process, the picture of the entire combustion process (12s) was superimposed. The total distribution of OH in the whole process are shown in Fig.2, In addition, the intensity profiles on the horizon ($z=0,20,40,60$) are shown in Fig.3.

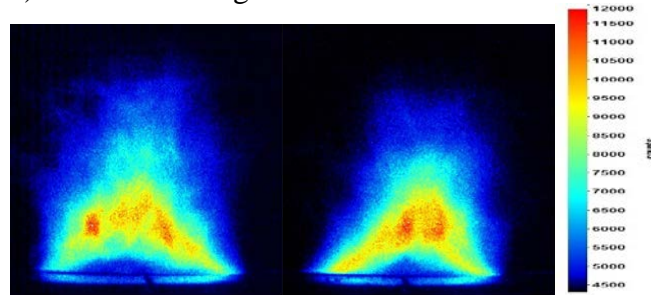


Fig.2 OH total distribution

From the OH of Fig.2, it can be seen that the distribution of the OH intensity of the pulverized coal after being pickled is weaker than that of the raw coal, and the whole OH range is smaller than that of the raw coal. That is to say, the combustion range of the pulverized coal after acidification will be smaller, which is beneficial to reduce the slagging on the heating surface [12]. Because it is complete combustion, the H element in OH comes from the pulverized coal completely, in other words, after pickling treatment of pulverized coal, the content of H element will be reduced, which is consistent with the ultimate analysis of the two pulverized coal. It also reflects that using instantaneous measurement PLIF to monitor is effective.

From the distribution of OH at different heights of Fig.3, the area covered by the distribution line and the time axis is the total content of OH at this height. When $Z=0\text{mm}$ and $Z=20\text{mm}$, the total content of OH on the horizontal axis is approximately equal, and when $Z=40\text{mm}$ and $Z=60\text{mm}$, the total distribution of OH on the horizontal axis is obviously different. The OH distribution range of acidified coal powder is smaller than that of raw coal, while the OH value is nearly equal. That is to say, the total amount of OH in the raw coal is more than that of the coal which has been treated by acidification, and further explained in terms of content that the content of H element in the pulverized coal is reduced.

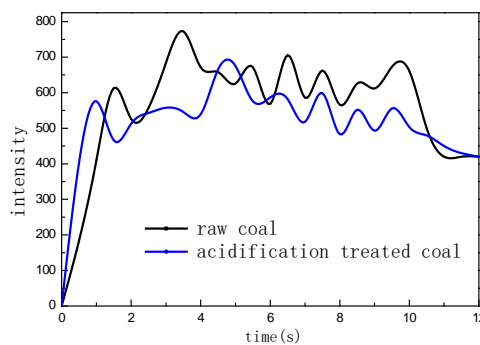


Fig.3 The maximum intensity of the process

3.2 Maximum intensity of OH process

From Fig.2 and Fig.3 we know that the amount of total OH in the acidified coal is reduced. In order to compare the precipitation strength of OH in the whole combustion process, the maximum value of OH in the whole combustion process is shown in Fig. 4. From Fig.4, on the whole, the maximum value of OH in the whole process, that is, the most intense moment of combustion, the acidification of the coal will be delayed. However, the time for the end of burning of the raw powder is slightly ahead of schedule, which may be related to the decrease of alkali metal after treatd and the catalytic action weakened [13]. At the same time, the maximum intensity of OH releasing in combustion process is weaker, which is corresponding to the content of OH

Z=0mm

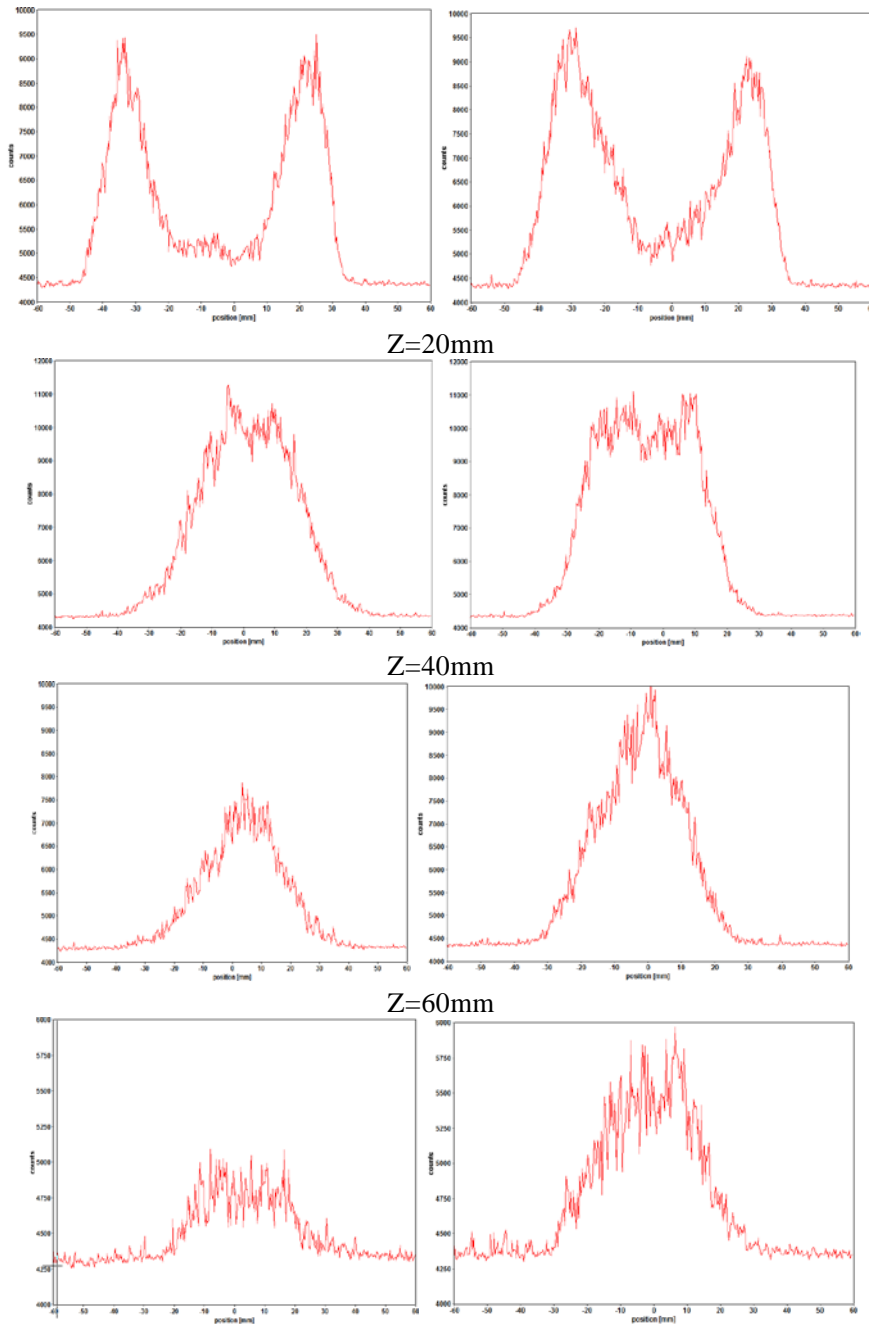


Fig.4 The distribution of OH at different heights

4. Conclusion

Planar laser-induced fluorescence (PLIF) was applied to a laboratory-scale pulverized-coal combustion burner, and the spatial relationship of the OH distribution was investigated by simultaneous measurement of OH-PLIF. To investigate the structure in detail, statistical analysis was performed using the intensity profile of OH-PLIF. The main results obtained in this study can be summarized as follows.

(1) It is found that the total content of OH in the whole process of pulverized coal after pickling is reduced, that is to say, the content of H in the treated pulverized coal will decrease, which is consistent with the result of elemental analysis.

(2) The coal powder treated by acidification has little change in the flame height, but it becomes smaller in width, that is to say, the flame is thinner than the raw coal, thus further reducing the slagging problem of the boiler heating surface, and making better use of the Zhundong coal.

(3) The most intense moment of coal combustion after acidification is delayed, and the peak value of each time is smaller than that of raw coal, which is consistent with the small content of OH.

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