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Experimental Study on Combustion Characteristic of Yellow Phosphorus Tail Gas

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Abstract

The field experiments simulate the combustion characteristics of yellow phosphorus tail gas by using homemade experimental apparatus. Results show that the change of excess coefficient of atmosphere has greater impact on the combustion temperature and the composition of flue gas. When the coefficient is 1.3, the yellow phosphorus tail gas achieves complete combustion state and the result of combustion of yellow phosphorus is best. The content of carbon monoxide which is in exhaust fume is the lowest.

Keywords: yellow phosphorus tail gas, combustion characteristic, combustion temperature, composition of flue gas;

1. Preface

In China, along with the environmental pollution has become a serious problem and fossil fuel shortage, the government has strengthened the policy supporting and assessment index of energy saving and emission-reduction and resource comprehensive utilization in industrial enterprises [1]. Yellow phosphorus is a basal chemical material. In 2009, the production capacity of yellow phosphorus has reached to 2,300,000 t/a in China. A large number of tail gases from yellow phosphorus production were burned into atmosphere without any treatment. It not only caused serious environment pollution, but also wasted a lot of resources [2, 3].

Each ton of yellow phosphorus production, there will be 2500-3000m^3 tail gas produced simultaneously which contains 75% to 90% of the carbon monoxide. And the heat value of tail gas reaches 11000kJ/Nm^3. It is believed that yellow phosphorus tail gas is a gas resource with high utility

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value [4]. In present, the main utilization of yellow phosphorus tail gas is still as fuel for boiler combustion and a gas generator. Study on combustion characteristics of yellow phosphorus tail gas has no related reports and plays an important role in analysis of the corrosion problem of yellow phosphorus tail gas [5]. In this paper, the field experiments simulate the combustion characteristics of yellow phosphorus tail gas by using homemade experimental apparatus and obtain the data of combustion characteristics of yellow phosphorus tail gas, having guiding significance for practical use of yellow phosphorus tail gas[6-9].

2. The composition of yellow phosphorus tail gas

The main producing way of yellow phosphorus is electric furnace smelting. Due to differences in phosphate rock and coke, yellow phosphorus tail gas containing composition fluctuates in a certain range. In this experiment, tail gas composition changes are shown in table 1.

Table 1.The composition of yellow phosphorus tail gas

volume（%）				concentration(g/Nm^3)			
CO	CO_2	O_2	others	S	P	As	F
75-80	2-4	0.2-0.5	3-5	0.5-2.0	0.5-1.0	0.07-0.08	0.4-0.5

3. Methodology

The experiment uses a set of self-designed device, which simulates the combustion process of yellow phosphorus tail gas and tests the characteristic of fuel gas.

3.1. Experimental systems

The experimental system of combustion characteristics of yellow phosphorus tail gas is shown in figure 1.

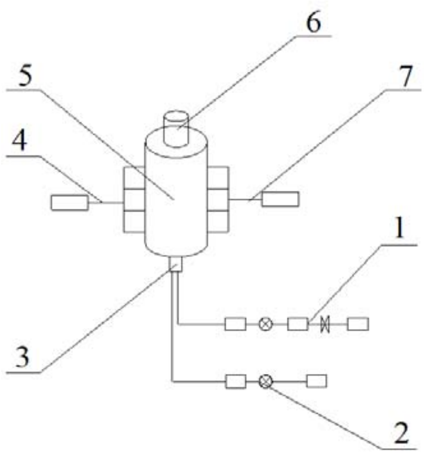

Fig.1.The experimental system of combustion characteristics of yellow phosphorus tail gas

1-Yellow phosphorus tail gas intake system; 2-Air distribution intake system; 3-Burner; 4-Flue gas composition detector; 5-Insulated combustion chamber; 6-Chimney; 7-Temperature data detector.

The height and inner diameter of combustion chamber are 1300mm and 100mm respectively. The burner inserts into the combustion chamber at the height of 70mm. There is an ignition and observation hole on the combustion chamber. From the bottom of the combustion chamber 100mm, 300mm, 600mm, 1000mm position, there will be reserved 4 thermocouple jacks and 4 gas analyzer holes on both sides of the position respectively, used for determination of the combustion temperature and flue gas testing. Analysis radial variation of temperature by measuring the distance 0mm, 10mm, 20mm, 30mm, 40mm, 50mm to furnace center.

3.2. Measurement methods

FULI9790 Gas Chromatograph, to detect the volume fraction of CO, O_2 in combustion flue gas; HC-6Trace sulfur and phosphorus Analyzer, to detect quality concentration of SO_2, H_2S, CO_2 in combustion gases; Gas analysis apparatus Orsat with four absorption pipettes, to detect volume fraction of CO_2 in combustion gases; WRN-B Platinum-rhodium thermocouple, to detect combustion temperature.

4. Results and analyses

The components of tail gas fluctuate within a certain range, because of the filed simulation experiment. Take the average of several experiments as conclusion.

4.1. The relationship between excess coefficient of atmosphere and core temperature of combustion chamber

Figure 2 shows changing trends of core temperature of combustion chamber under the different excess air coefficient. From the figure, in the same excess air coefficient, with the increasing height of furnace ,the core temperature of combustion chamber raises sharply then drops slowly, and reaches peak at the height of 300mm. Yellow Phosphorus tail gas contains a lot of CO and a small amount of H_2. After ejecting from the burner and the air fast mixing combustion, the flames spread faster, determining the top of flame at the bottom of combustion chamber.

The data in figure 2 shows that the burning point of yellow phosphorus tail gas is between 560℃ and 640℃. The temperature detecting at the height of 100mm is the burning point due to measuring point is near the burner. With the excess air coefficient α increasing, the combustion temperature curves are increased overall. When the height is 300 and the coefficient α is 1.3, the combustion temperature reaches highest value and achieves complete combustion. From the two curves $\alpha=1.4$ and $\alpha=1.5$, the trend of combustion temperature declines slowly at 600mm, due to the air velocity increased when the excess air coefficient $\boldsymbol{\alpha}=1.3$ increased. But excessive excess air coefficient will lead to lower combustion temperature.

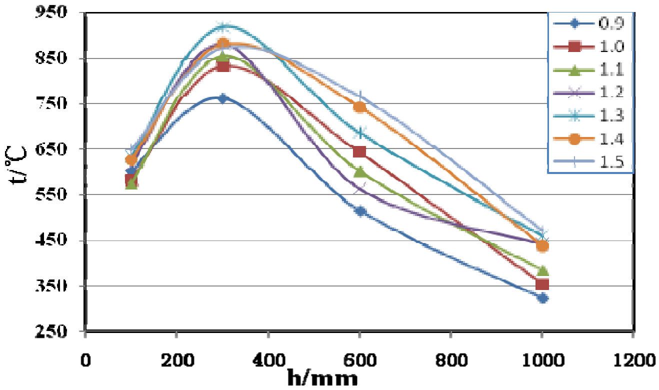

Fig.2. The temperature distribution of combustion chamber center under different conditions of excess air coefficient

4.2. The relationship between excess air coefficient and radical temperature of combustion chamber

Figure3 illustrates the changes of radical temperature of combustion chamber with excess air coefficient. As shown in Figure3, under the same excess air coefficient, tendencies of radical temperature of combustion chamber decline gradually with the increasing distance to combustion chamber center. The changes of temperature are not obvious in the context of 0-18mm.The downward tendencies of temperature increase in the range of 20-40mm. However, they are easing when close to the furnace wall and not obvious.

Experimental curves in Figure3 also show, under the different excess air coefficient, maximum temperature almost appears in furnace center. It directs the location where achieve the best combustion. Nevertheless, when the excess air coefficient α=1.4 and α=1.5, maximum temperature appears at the position from combustion chamber center 10mm. It directs that, under this condition of excess air coefficient, the flame height changes. And the middle temperature of this measuring point is no longer a maximum. The flame height has increased.

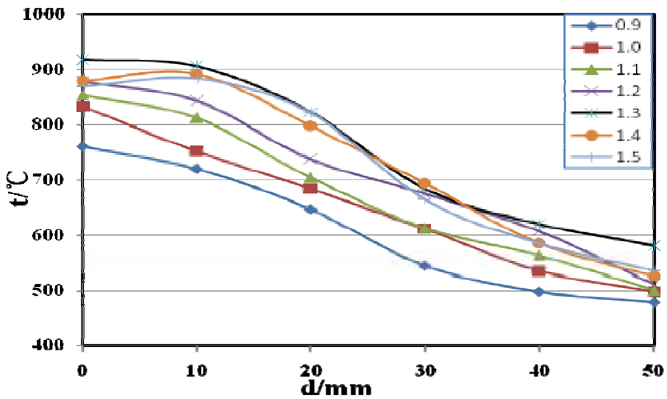

Fig.3. Distribution of radical temperature of combustion chamber under different excess air coefficient

4.3. The relationship between O_2, CO, CO_2 volume fraction in flue gas and the change of excess air coefficient

Figure 4 illustrates O_2, CO, CO_2 volume fraction in flue gas under different excess air coefficient. The content level of O_2, CO, CO_2 determines the flue gas burning completely or not. The curves in figure 4 shows, O_2 content in flue gas increases slowly with the excess air coefficient increasing. And when α=1.3, the increasing tendency is obvious. Corresponding the CO change tendencies and the temperature change range in Figure2, α=1.3 can be seen as the best excess air coefficient and the tail gas combustion reaches completely.

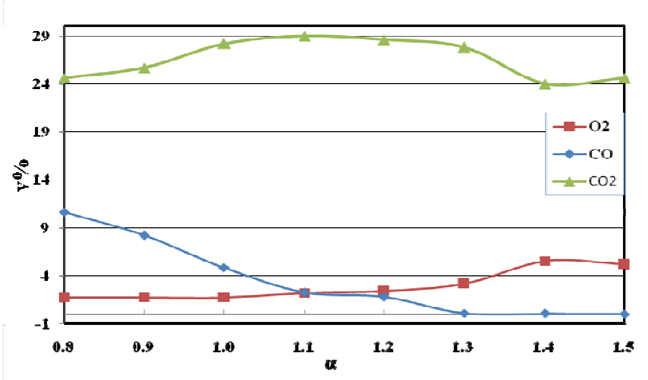

Fig. 4.The changes of O_2, CO, CO_2 volume fraction in flue gas with different excess air coefficient

4.4. The relationship between SO_2, H_2S, COS concentration in flue gas and the change of excess air coefficient

Analysis of the change of sulfur in flue gas has guiding significance in analysis of industrial boiler emission. The curves in figure5 illustrate that SO_2 concentration in flue gas increases then declines with excess air coefficient increasing. The concentration of SO_2 takes its maximum value at a range of α=1.2-α=1.3. Under the condition of α＜1.2, sulfur-containing components in tail gas generate SO_2 by burning. Under the condition of α＜1.2 and excess air and high temperature, sulfur dioxide generated oxygenizes into SO_3 by burning, plus dilute excess air, and the sulfur dioxide concentration declines.

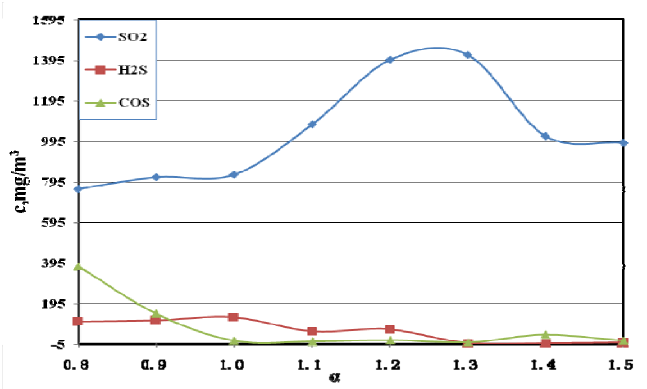

Fig.5.The changes of SO_2, H_2S, COS concentration in flue gas with different excess air coefficient

5. Conclusion

The temperature of combustion chamber fist increases then declines slowly with the increasing excess air coefficient **α**. It takes maximum temperature at the height 300mm. But under the condition of **α**＞1.3, the temperature declines.

The radical temperature of combustion chamber declines with the increasing distance to combustion chamber center under the same excess air coefficient. From beginning to the end, the maximum temperature distributes 0-18mm location from combustion chamber center.

The changes of O_2, CO concentration in flue gas reflect the situation of tail gas combustion. Between **α**=0.8-1.3, the CO concentration declines; when **α**⩾1.3, the CO concentration takes minimum value. Corresponding to the change tendency of O_2, it can be concluded that the best excess air coefficient is **α**=1.3.

Under the condition of different excess air coefficient, the SO_2 concentration in flue gas increases with the combustion of sulfur content in tail gas. It appears inflection between **α**=1.2-1.3, due to excessive amount of air supplying and high temperature, SO_2 is oxidized to SO_3 and SO_3 will be exhausted finally. So the tendency of SO_2 concentration declines.

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