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Original Paper

Experimental Study of a Pulse Combustor's Tail Gas

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Abstract

Pulse combustion is a periodic oscillating combustion process. Compared to traditional steady combustion, it is of high combustion efficiency and heat transfer coefficient, little emissions of pollution, simple structure and so on. This paper focused on emission characteristics of NO_x and CO in the process of pulse combustion. The strong air flow in the pulse combustion chamber improved the mixing process for complete combustion, so that the content of NO_x, CO of the tail gas was reduced.

Keywords

pulse combustion, tail gas, little emissions of pollution

1. Introduction

Pulse combustion is a periodic oscillating combustion process, and the state parameters in the combustion region such as pressure, temperature and heat release rate change periodically over time. Pulse combustion is mostly self-excitation generated. Compared to traditional steady combustion, it is of high combustion efficiency and heat transfer coefficient, little emissions of pollution, simple structure and so on. These advantages can be applied to drying process to enhance heat and mass transfer and improve drying conditions. High-temperature, high-frequency oscillatory tail gas and strong acoustic energy can be used for drying which is a very good drying medium to enhance heat and mass transfer process and improve drying efficiency (Keller, German, & Ozer, 1992). The fluctuations of the pressure, temperature, velocity and composition in a combustion chamber's tail pipe were analyzed. This paper focused on emission characteristics of NO_x and CO in the process of pulse combustion.

1.1 Structure of Pulse Combustor

The experimental apparatus is a Helmholtz-type pulse combustor fitted with a flapper valve and power range of 75kW or so. Fuel is liquefied petroleum gas. Helmholtz-type pulse combustor is constituted by the combustion chamber, tailpipes, air valves and fuel supply system, etc. As the one-way air flapper valve structure of the combustor is more complicated. The air and fuel pipes are into a 90° angle. Air and fuel goes through their pipelines into the combustion chamber after mixing with each other, and mixed gas is ignited by spark plugs, and the combustion gas goes into the tailpipe from the combustion chamber.

In this paper, the pulse combustor and the boiler consist of the six pulse combustors and a water tank were tested. The pulse combustor did not have the water tank, and the other six pulse burners arranged in three rows and two in each row.

2. Methods and Instruments of Testing Pulse Combustion's Tail Gas

This test focused on NO_x and CO formation characteristics of the law in the pulse combustion process, so the measurements of NO_x and CO and other components from the flue gas is the most basic and essential. The components and other physical parameters of flue gas were measured by the flue gas analyzer 350Plus produced by German Testo.

3. Analysis and Discussion of Results

3.1 The Comparison of Tail Gas

Single pulse combustor without water tank was tested. The oxygen content is about 14% and CO levels are very small- only 4.4 ppm, which shows a very complete combustion of propane; NO accounted for the major part of NO_x and is greater than 30ppm; the temperature of tail gas is 370 ℃ or so because there is no cooling water. As to the same combustor with water tank, the oxygen content is less and about 10%, and CO content vary greatly from 15 to 1000ppm, and NO also accounted for the major part of NO_x and is about 40ppm, but the temperature of tail gas is low and about 67 ~ 160 ℃ because of cooling water.

3.2 Composition Analysis

3.2.1 NO_x Generation in Pulse Combustor

The paper pointed out that in conventional gas boiler NO_x generation amount is in the range of 58 ~ 138ppm, compared with only 34 ~ 46ppm of the pulse combustion generation (Keller & Hongo, 1990).

The strong pulse of the air flow inside pulse combustion improved the mixing process in combustion chamber, and the combustion is complete, so exhaust emissions of CO, NO_x and soot and other content was decreased. As excess air is low, the temperature in combustion chamber is lower, NO_x emissions is only (20 ~ 50) $x10^{-6}$; using of certain measures, NO_x emissions can be reduced to (5 ~ 7) $x10^{-6}$ (Keller & Hongo, 1990).

NO accounted for the major part of NO_x, and the content was in the range of 4 ~ 40ppm and rises with the exhaust gas's temperature increased. On the contrary, the content of NO_2 was less and reduced with the exhaust gas's temperatures increased.

Due to the strong airflow pulsation inside the pulsation burner, the mixing process of gas in the combustion chamber was improved, and the gas was fully burned, resulting in an overall decrease in the NOx content in the exhaust gas. NOx emissions decreased with the increase of excess air coefficient (Xu, Zhai, Dong, & Zhu, 2015). This is the influencing factor for the overall decrease in NOx content.

3.2.2 CO Generation in Pulse Combustor

CO concentration was less than 600ppm, theoretically the lower the CO content should be the higher the O_2 content should be. Contents of NO_x increased with the tail gas temperature rises and CO contents decreased. NO_x and CO changes in the lower range of the content, even the highest level between the two is far smaller than the state's gas-fired boiler emission standards (NO_x≦195ppm, CO≦ 1000ppm).

CO emission is low due to the role of pulse, so air and fuel can mix better and burn more fully. Tail gas went through a long journey from the combustion chamber to the tail pipe, in the process it was good for gas full combustion that CO of tail gas and the remaining O_2 exposed longer (Feng, 2021).

4. Conclusions

1) Flue gas is produced in the combustion process of Helmholtz-type pulse combustor, among which NO is the main part of NO_x, but the content is small. With the temperature of the flue gas, the overall content of NO_x in the flue gas decreases. Due to the strong airflow pulsation in the pulse combustor, large combustion excess air coefficient and low combustion chamber temperature, the NO_x emission in the flue gas is reduced.

2) The CO content in the flue gas produced in the combustion process of the pulse combustor is less, and the CO content decreases with the increase of O_2 content. Because the CO in the flue gas in the combustion process and the remaining O_2 have a long contact mixing time, it is conducive to the full combustion of gas and the CO emission is low.

3) There is a periodic oscillating combustion process in the pulse combustor chamber. The strong airflow pulsation improves the mixing process and makes the gas completely burned, thus reducing the content of NO_x and CO in the flue gas. The pulse combustor after adding the water tank produces flue gas. The temperature of the flue gas decreases because of cooling water, the content of NO_x and CO decreases, and the flue gas at different temperatures can be applied to different drying equipment and furnaces. The experimental research lays a foundation for the application of pulse combustor in drying equipment.

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