Journal of University of Science and Technology Beijing
Vol.8(2001), No.4, p.264

Metallurgy

Extra Low NO_x Emission Furnace with HTAC Technology

Yunze Guan, Daqiang Cang, Xiongfang Nie, Hao Bai, Xianzhao Zhang

Metallurgy School, University of Science and Technology Beijing, Beijing 100083, China
(Received 2001-03-01)

Abstract: HTAC (High Temperature Air Combustion) technology needs high temperature air and low oxygen atmosphere to complete its unique combustion and achieve extra low NO_x production. In order to apply HTAC technology to forge furnace and meet the NO_x emission standard, exhaust gas regeneration technology in combination with no-fuel-switch and U-shape air circulation methods was applied on forge furnace. The results show that extra low NO_x emission ($NO_x = 2.9\times10^{-5}$, in volume fraction) could be obtained, the NO_x emission meets the standards of Japan and US, HTAC mechanism is discussed finally.

Key words: combustion; HTAC; NO_x emission; flue gas regeneration; no-fuel-switch; pollution control

1 Introduction

High Temperature Air Combustion (HTAC) is a newly developed technology for fuel combustion with much higher efficiency and good environmental protection. With HTAC technology, the furnace temperature distribution is uniform. Compared to the traditional combustion, this new technology provides significant energy savings (up to 60%). Another prominent characteristic of HTAC is low NO_x emission and low noise during the combustion process [1–4].

NO_x is formed via several ways with different mechanisms during the combustion, but it is considered prior to the temperature increase and oxygen content [5].

The specific applications of HTAC need to solve two difficulties: one is how to get high temperature air, and the other is how to get low oxygen atmosphere. Furthermore, the latter is more important in specific applications. In practice, engineers often use three sorts of method to achieve low NO_x emission during the combustion process: (1) air staged combustion, (2) fuel staged combustion and (3) flue gas recirculation. A creative no fuel-switch technology integrated with U-shape air circulation and flue gas regeneration was adopted in the experiments, and the results showed that extra low NO_x emission was obtained successfully.

2 Experimental Facility

The laboratory test was carried out in a forge furnace in which completes HTAC combustion, while a creative way to provide fuel and combustion air was implemented. That is so-called "no-fuel-switch" and combustion air U-type circulation technology, and thus these measures simplify the system and operation in the meantime. The schematic diagram of the test furnace is shown in **figure 1**.

The measurements were carried out by several instruments or equipments: furnace temperature was me-

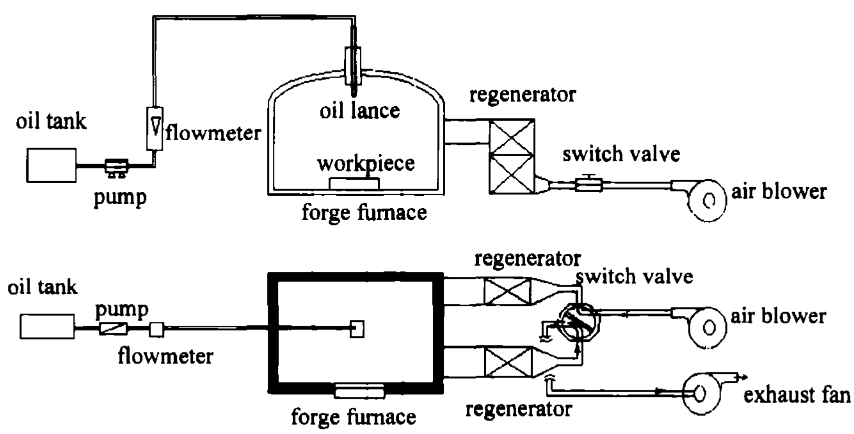

Figure 1 Schematic sketch of forge furnace.

asured by NiCr-NiSi thermocouples, air flow rate measurement was shown by a hot-wire anemometer and gas concentration was indicated by a German-made NO_x-SO_2 MSI150 instrument. This instrument can indicate the gas concentration of O_2, CO_2, CO, NO_x and SO_2 simultaneously.

The forge furnace bottom suface of 1.3 m^2 was made of high alumina brick, while the rest of the furnace lining was all made of chamotte.

The regenerating system could preheat the combustion air up to more than 1 000℃ and furnace temperature up to 1 350℃, and the heat accumulator is a kind of clay ripple-like slab which is shown in **figure 2**. Switch valve is made of steel, and it switches at regular time intervals after initialization (45 s in experiments).

The light diesel oil is used as fuel. Two regenerative chambers recover the energy of exhaust gas and the combustion air is preheated to the temperature only lower 50–100℃ than the flue gas.

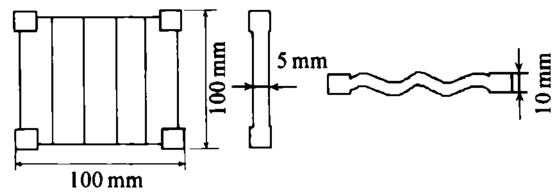

Figure 2 Schematic diagram of heat accumulator.

3 NO_x Emissions

When the flue gas regeneration technology was adopted for the forge furnace, the best results occurred in the experiments. The exhaust gas contains (volume fraction) NO_x: 2.9×10^{-5}, CO: 1.2×10^{-5} and SO_2: 2.3×10^{-5} respectively. At the moment, O_2 content is 14.2% (volume fraction) and exhaust gas temperature is 128℃. While the advanced Japanese and American NO_x emission standards are 1.3×10^{-4}–1.8×10^{-4} (liquid fuel, Japan) and 2.2×10^{-4}–4.0×10^{-4} (liquid fuel, American) [6]. **Figure 3** shows the results.

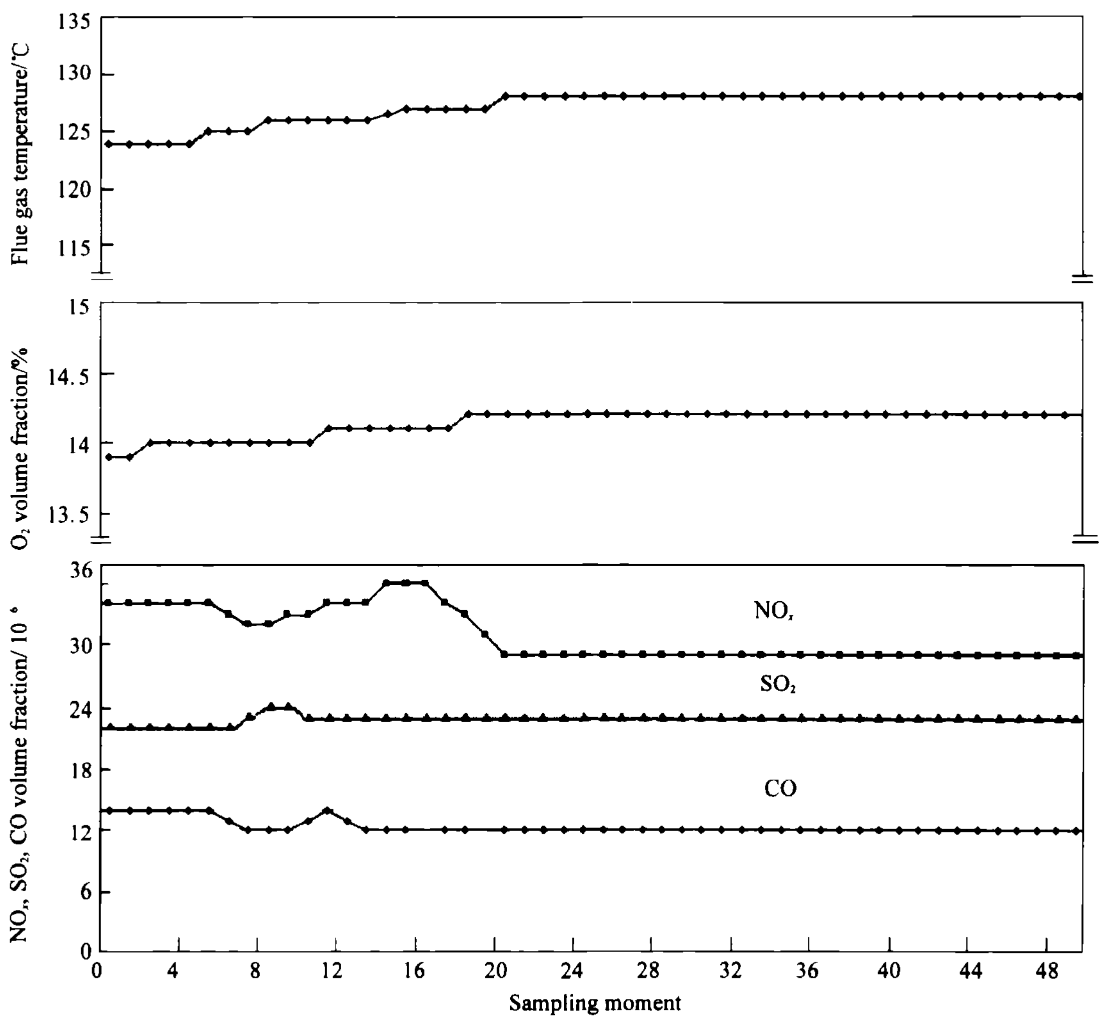

Figure 3 Measurement results of flue gas regeneration.

4 Discussion

HTAC technology must meet two conditions: (1) combustion air must be preheated up to high temperature ($\geq$800℃), then flames can keep stable; (2) extra low NO_x emission can only be obtained under the condition of low oxygen content. Low oxygen combustion was sustained by high temperature combustion, while high temperature combustion need low oxygen atmosphere to ensure low NO_x emission. Due to the optimum heat recovery from the flue gas transfering to comfustion air by regenerators, the highly preheated air hence provides excellent conditions in thermodynamics and kinetics for the low oxygen combustion. Above all, the diffusion and mixture between fuel and oxygen molecules are enhanced under high temperature, and the mixture becomes more rapid and uniform compared to conventional combustion. Furthermore the uniform mixture is taken place in the combustion zone. So thecontact interface between the fuel and oxygen disappears. Secondly, once the fuel molecule meets the need of chemical reaction for oxygen molecule, the combustion reaction occurs immediately, and owing to the excellent diffusion condition, the reaction happens everywhere in the combustion zone. Thirdly, the presence of activated molecules or radicals due to the thermal decomposition of fuel under low oxygen and high temperature conditions play an important role in diffusion process and combustion reaction, since these radicals possess higher activity. Furthermore, these radicals are reductive, so suppress the NO_x production greatly.

5 Summary

With the no-fuel-switch, combustion air U-type circulation and flue gas regeneration technology, extra low NO_x was successfully obtained. It is also confirmed that HTAC is a promising technology in combustion area. HTAC could be used in various applications, such as boilers, melting, reheating, soaking, heat treatment furnaces etc. Further HTAC technology is great potential in various applications.

References

[1] A. K. Gupta : [in]*Proc. of 2nd International Seminar on High Temperature Combustion in Industrial Furnaces*. Stockholm, 2000, p.1.

[2] R. C. Chang, W. C. Chang, W. C. Chen, et al:[in] *Proc. of HTAC new technology*, Beijing, 1999, p. 140.

[3] H. C. Zhou, F. Sheng, H. Yao, et al: *gongyelu* (in Chinese), 20(1998), No.1, p.19.

[4] H. Y. Qi , X. C. Xu : [in]*Proc. of HTAC new technology*, Beijing, 1999, p.192.

[5] C. B. Xu : *Study on mechanism and new controlling technology of NO_x formation during combustion of coal/coke in packed bed*: [Ph. D. thesis]. Beijing:Univ.Sci.&Tech. Beijing, 1998, p.10.

[6] J. X. Zhao : *Exhaust pollution and noise by heat dynamical equipment* (in Chinese). Science Press, Beijing, 1995.