

Analysis and optimization on SNCR De-NO_x system of a MSW incinerator

Maodong Li^{a*}, Bo Yang^b and Xiaocong Wang^c

Guangzhou Special Pressure Equipment Inspection and Research Institute,
Guangzhou, 510100, China

^a 2453962572@qq.com, ^b 272818102@qq.com, ^c 181795652@qq.com

Keywords: Selective non-catalytic reduction; Municipal solid waste; Incineration; Optimization.

Abstract. The SNCR De-NO_x system is an effective denitration technology for MSW incinerator. In this paper, an economic parameter-S: per unit NO_x removal cost was established. The results clearly showed that parameter S has a significant change at different loads. The 90% load had the lowest per unit NO_x removal cost which was 1.61 RMB/h. It was worth noting that SNCR system had an optimal flow of the reducing agent under different loads. In addition, due to the concentration of NH₃ escape in fuel gas, therefore needs to consider comprehensively the economic and environmental benefits during SNCR operating. These parameters allowed the operator to monitor the SNCR of economic and environmental benefits index more intuitively. With the improvement of technology and experience accumulated, the SNCR technology operation optimization can further reduce NO_x in MSW incinerator.

Introduction

In recent years, the improvement of living standards and social development has lead to a remarkable increasing yield of municipal solid wastes (MSW) in china¹. Among the MSW thermal disposals, incineration of MSW is widespread worldwide due to its capabilities of significantly reducing the volume of wastes and producing heat energy for electricity². With the increasingly strict environmental laws, the control of NO_x emission from MSW incinerators has become increasingly important. Accordingly, implementations of high-efficiency NO_x removal technologies are mandatory for newly constructed waste incinerators in China³.

Selective non-catalytic reduction (SNCR) is a de-NO_x technology that has been considered as an economic and effective post-combustion flue gas treatment technology. During SNCR de-NO_x process, nitrogen reducing agents (such as NH₃) were injected into flue gas stream containing NO_x at a temperature near 1000 °C to selectively reduce NO_x in molecular nitrogen (N₂) in the absence of expensive catalyst^{4, 5}. The process can be expressed as the following chemical reaction equation:



Although the SNCR has been demonstrated to achieve 80–90% and 40–70% NO removal efficiency in pilot scale experiment⁴ and full scale facility⁶, respectively. However, due to the variability of MSW composition, load variation and furnace temperature, the efficiency of SNCR in MSW incineration plant failed to achieve the design value. Therefore, analysis and optimization on SNCR De-NO_x system of MSW incinerator is an important topic that affects the safety and economy of incinerator operation.

Analytic target and Methods

Incinerator description. In this paper, the MSW plant was a 750 t/day incinerator located in Guangzhou. The more information could be found in the published literature³. The nitrogen reducing agents of SNCR was 25% aqueous ammonia solution. The average compositions of MSW in first quarter of 2015 were listed in Table 1.

Table 1. The average compositions of MSW in first quarter of 2015 (%)

Moisture	Food	Rubber	Fiber	Paper	Inorganic	Other	Low heating value (kJ/mol)
55.1	6.4	11.6	8.9	16.9	0.4	0.7	7767

The NO_x removal efficiency of SNCR system was defined as following equation:

$$\eta_N = (\text{NO}_{x1}) / (\text{NO}_{x2}) \times 100\% \quad (2)$$

where η_N was the NO_x removal efficiency, %; NO_{x1} was the NO_x emission without SNCR system, mg/Nm³ (11% O₂ on dry basis); NO_{x2} was the NO_x emission with SNCR system, mg/Nm³.

In addition, to evaluate the economy of SNCR system under different load, the per unit NO_x removal cost was proposed by following:

$$S = (M_a \times Y_a + M_w \times Y_w) / (\text{NO}_{x1} - \text{NO}_{x2}) \quad (3)$$

Where S was the per unit NO_x removal cost, RMB/(mg×Nm³); M_a and M_w were the flow of 25% aqueous ammonia solution and the water for SNCR injection, L/h; Y_a and Y_w were the price per unit of 25% aqueous ammonia solution and the water for SNCR injection, which were 1700 and 2.53 RMB/t, respectively.

Results and discussions

SNCR operation characteristic analysis. Figure 1 showed the NO_x emission before and after SNCR system operation. As showed in Figure 1, the NO_x emission values with SNCR under different load all meet the current Chinese Environmental Protection Standard (200 mg/Nm³). This suggested that SNCR was an effective de-NO_x system for MSW incinerator. From figure 1, it could also find that the NO_x emission rose with the load increasing. The possible reasons could be attributed to the follows. Firstly, the formation of NO_x in the flue gas is mainly contributed by the oxidation of nitrogen containing constituents in the wastes³. With the load increasing, more MSW was needed to the boiler furnace for incinerating. Consequently, the NO_x emission was increased. Secondly, the boiler furnace temperature also increased with the load increasing which made a contribution to the generation of NO_x⁷.

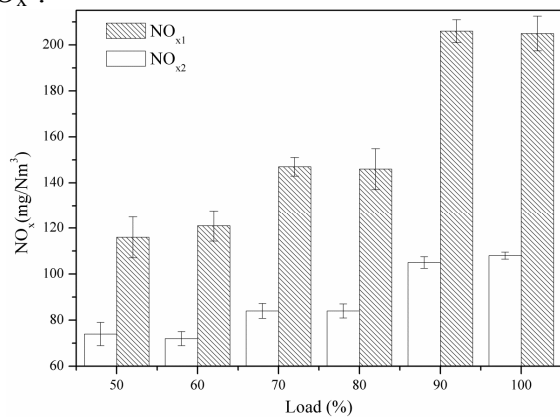


Figure.1. The NO_x emission before and after SNCR system operation

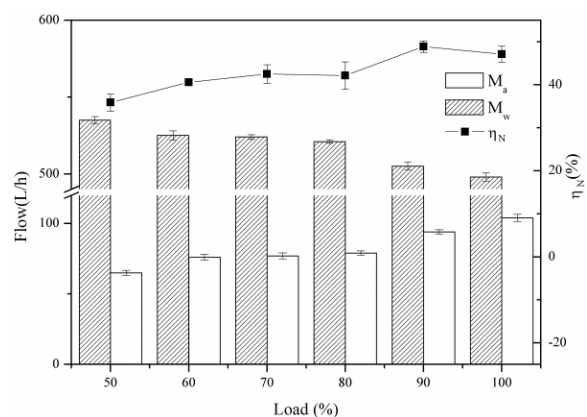


Figure.2. The SNCR system operation parameters under different load

Figure 2 displayed the SNCR system operation parameters under different load. As it showed, the SNCR had the higher NO_x removal efficiency with 48.86% at 90% load, followed by 47.11% at 100% load and 42.49% at 70% load, respectively. Moreover, the SNCR had the lowest NO_x removal efficiency with 35.88% at 50% load. Overall, the NO_x removal efficiency exhibited an upward trend with the load increasing. Figure 2 also given two key operating parameters: the flow of 25% aqueous ammonia solution (M_a) and the water for SNCR injection (M_w). In order to ensure the atomization effect of aqueous ammonia jet to the furnace, the sum of the aqueous ammonia solution and the water

for SNCR injection was kept as a constant value. Hence, M_a increased with the load increasing while M_w showed the opposite trend. As mentioned above, more NO_x generated at high load. Therefore, there needed more aqueous ammonia restore NO_x to N_2 .

SNCR optimization analysis. The boiler efficiency and per unit NO_x removal cost were the key indexes for evaluating the economic benefit and environmental benefit of MSW incineration. The operator adjusted the boiler operation parameters according to these indexes, in order to ensure the boiler running under optimum operating conditions. Figure 3 displayed the boiler efficiency and per unit NO_x removal cost of MSW incinerator. As showed in Figure 3, the boiler efficiency increased with the load increased. The boiler efficiency had the highest value with 80.7% when the load reached 100%. Then, the boiler efficiency steadily decline with the load decreasing. The boiler efficiency of 90%, 80%, 70% and 60% load were 80.5%, 78.7%, 74.6% and 74.6%, respectively. While when the load decreased to 50%, a sharp drop (65.6%) was observed. This indicates that the load should be kept at a higher level in the operation of MSW incinerator so as to maintain its high boiler efficiency and ensure its economic benefit. As also showed in Figure 3, it could be clearly seen that per unit NO_x removal cost has a significant change at different loads. The 90% load had the lowest per unit NO_x removal cost which was 1.61 RMB/h. Therefore, at this time, the environmental benefit of MSW incinerator was best. The possible reason was that atomized reducing agent and NO_x have been sufficient contact under 90% load, making the highest denitration efficiency. And then the per unit NO_x removal cost of 100% was 1.84 RMB/h. The per unit NO_x removal cost of 50% load was highest, reached 2.71 RMB/h.

In the process of SNCR denitrification, the reducing agent NH_3 which did not involved in the reduction reaction would be discharged together with the flue gas from the furnace to the atmosphere. As we known, NH_3 emissions into the atmosphere is harmful to humans and the environment. Hence, in the SNCR system, the NH_3 emissions concentration need to be the key data for the detection. As showed in Figure 4, with the load and aqueous ammonia solution increasing, the NH_3 emissions concentration rose constantly, 8.5% for 100% and 90% load, 7.5% for 80% and 70% load, 6.5% for 60% and 50% load, respectively.

With the load increasing, more MSW was needed which resulted in increasing aqueous ammonia solution and fuel gas. This has taken part of the NH_3 to a certain extent, and thus resulted in an increase in the emissions of NH_3 at high loads.

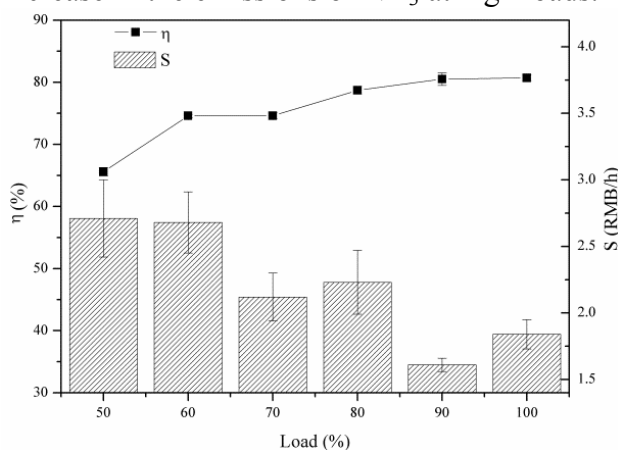


Figure. 3. The boiler efficiency and SNCR economic parameter-S

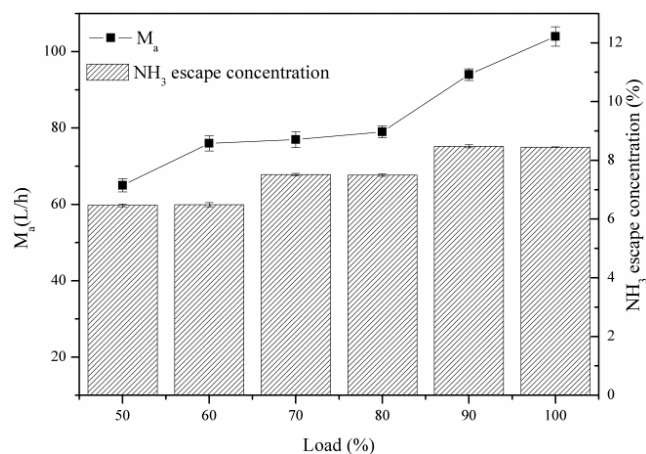


Figure.4. The aqueous ammonia solution flow and NH_3 escape concentration

Conclusions

1. Under different loads, SNCR system had an optimal flow of the reducing agent. Continue to increase the flow of the NO_x removal efficiency would slightly improve a little, but reducing traffic consumption would increase significantly.

2. There are many factors that affect the NO_x removal efficiency of SNCR, besides the flue gas temperature, the NO_x content and the reducing agent flow also had some effect on the efficiency. When the load and the reducing agent solution increased, although the NO_x removal efficiency could be improved, but the concentration of NH₃ escape would rise, and therefore needs to consider comprehensively the economic and environmental benefits. With the SNCR technology, the NO_x emissions of the MSW incinerator can meet the national environmental protection requirements.
3. In this paper, an economic parameter-S: per unit NO_x removal cost was established. This parameter allows the operator to monitor the SNCR of economic and environmental benefits index more intuitively, and have a significant effect on the optimization operation of MSW incinerator.
4. The engineering practice of SNCR in MSW incineration is still lack of sufficient relevant experience data. With the improvement of technology and experience accumulated, the SNCR technology operation optimization can further reduce NO_x in MSW incinerator.

Acknowledgements

This study is supported by the General Administration of Quality Supervision, Inspection of Public Projects (20140159) and Guangdong Province Key Laboratory of Efficient and Clean Energy Utilization (2013A061401005).

References

- [1] Zhou, H.; Meng, A.; Long, Y.; Li, Q.; Zhang, Y., An overview of characteristics of municipal solid waste fuel in China: Physical, chemical composition and heating value. *Renewable and Sustainable Energy Reviews* 2014, 36, (0), 107-122.
- [2] Zhou, H.; Meng, A.; Long, Y.; Li, Q.; Zhang, Y., A review of dioxin-related substances during municipal solid waste incineration. *Waste Management* 2015, 36, (0), 106-118.
- [3] Xia, Z.; Li, J.; Wu, T.; Chen, C.; Zhang, X., CFD simulation of MSW combustion and SNCR in a commercial incinerator. *Waste Management* 2014, 34, (9), 1609-1618.
- [4] Tayyeb Javed, M.; Irfan, N.; Gibbs, B. M., Control of combustion-generated nitrogen oxides by selective non-catalytic reduction. *Journal of Environmental Management* 2007, 83, (3), 251-289.
- [5] Nguyen, T. D. B.; Kang, T.-H.; Lim, Y.-I.; Eom, W.-H.; Kim, S.-J.; Yoo, K.-S., Application of urea-based SNCR to a municipal incinerator: On-site test and CFD simulation. *Chemical Engineering Journal* 2009, 152, (1), 36-43.
- [6] Gasnot, L.; Dao, D. Q.; Pauwels, J. F., Experimental and Kinetic Study of the Effect of Additives on the Ammonia Based SNCR Process in Low Temperature Conditions. *Energy & Fuels* 2012, 26, (5), 2837-2849.
- [7] Shao, L.-M.; Fan, S.-S.; Zhang, H.; Yao, Q.-S.; He, P.-J., SO₂ and NO_x emissions from sludge combustion in a CO₂/O₂ atmosphere. *Fuel* 2013, 109, (0), 178-183.