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EXPERMENTAL STUDY ON SEQUENCE HEATING REACTION BETWEEN NITRIC OXIDE AMMONIA

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ABSTRACT
A tubular reactor with a sequence heating device is used to discuss the effects of operational parameters for the reaction between nitric oxide and ammonia. Experimental results showed that denitration efficiencies had been developed to become a parabola with the change of reaction time under a certain NH_3/NO mole ratio and under a certain temperature and that denitration efficiencies also had changed to become a parabola with the increase of the reaction temperature when a NH_3/NO mole ratio was identified. Denitration efficiencies of 91.6 percent could be reached when the optimal NH_3/NO mole ratio, optimal reaction temperature, and reaction time respectively were 1.2, 320 ℃ and 14min in this work.

KEYWORDS: Nitric oxide, Ammonia, Sequence heating, Experiment, Denitration efficiency.

INTRODUCTION
Nitrogen oxide is one of the main pollutants of flue gas emitted by coal burning boiler, which has a large proportion in the air pollutant. In order to solve the pollution problem of nitrogen oxide in industrial production and in daily life, a great deal of measures of control and of emission reduction have been adopted. Currently control tactics and emission reduction measures commonly used in technology are NO_x control technology during combustion such as circulating fluidized bed combustion technology, low nitrogen combustion technology, integrated coal based combined cycle, NO_x control technology before combustion such as clean coal power generation technology and NO_x control technology with post-treatment after combustion such as flue gas denitration technology based on selective catalytic reduction (SCR), selective non-catalytic reduction (SNCR) and SCR/SNCR joint technology. Although these technologies of nitrogen oxide removal had had better effects for NO_x denitration efficiency, it still had broad research space to discuss their issues of gas mixing, transfer process and chemical reaction. Thus, a denitration reactor of selective catalytic reduction with a preheating section, a high temperature section and a reaction section for the mixed gas was used to investigate the effects of reaction time, NH_3/NO mole ratio and reaction temperature on denitration efficiency when nitric oxide and ammonia were flue gas simulated and reduction agent, respectively.

EXPERIMENTAL
Apparatus
The schematic diagram of the denitration unit is plotted in Figure 1. Steel cylinder 1, 2, 3 and 4 are filled with argon gas, oxygen gas, ammonia gas and nitric oxide gas, respectively. Flow controller 5 controls various gases from cylinder 1, 2, 3 and 4 by operational key panel. After the gases from cylinder 1, 2, 3 and 4 are premixed in pipeline 6 they will in turn pass the preheating section 8, high temperature section 9 and reaction section 10 purged by blower and simultaneously will react in these sections. Finally, exhaust gases are discharged by pipeline 11. In this system reactor 10 is a cylinder with size Φ100×650 which is filled with catalyst inside and is covered with thermal coat of insulation cotton outside. The catalyst is composed of TiO_2, V_2O_5 and WO_3 with a mass fraction of 0.9, 0.03 and 0.07.

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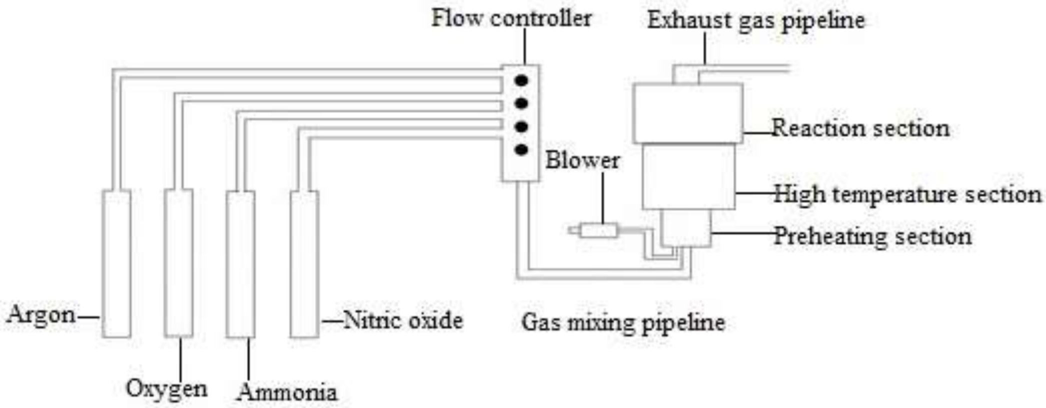

Figure 1 Schematic diagram of denitration unit

Procedure

1) Turn on power switch and open ventilation equipment to ensure that there is adequate ventilation in the laboratory. Then put the exhaust pipeline outlet to outdoors.

2) Turn on the switch of the equipment and open the air blower to ensure that gas flow of the reaction section is smooth. Afterwards, turn on switches of the preheating section and the high temperature section and set their temperatures value. After the temperature of the reaction section reaches the experimental temperature of 270 ℃, close the air blower.

3) Open steel cylinder valves of argon gas, oxygen gas and nitric oxide gas respectively and orderly and make volumetric flow rate in pipeline be 0.01 $L \cdot min^{-1}$, 0.01 $L \cdot min^{-1}$ and 0.38 $L \cdot min^{-1}$. Afterwards, open steel cylinder valve of ammonia gas and make its flow rate be 0.46 $L \cdot min^{-1}$. Adjust these four valves and make the NH_3/NO volumetric flow rate ratio is 1.2 and the time record begins.

4) Observe and record denitration efficiencies shown by data analyzer at 0 min, 5 min, 10 min, 15 min, and 20 min.

5) Adjust respectively the temperature of the reaction section to 290℃, 300℃, 320℃, and 350℃ and repeat abovementioned procedures. Afterwards, identify optimal reaction time.

6) Adjust and set respectively the NH_3/NO volume ratio to 0.8, 1.0, 1.2, 1.4 and 1.6 under reaction temperature 290℃. Repeat steps 1, 2, 3, and 4 when reaction time is optimal reaction time.

7) Repeat steps 1, 2, 3, 4, and 6 when the reaction temperature is respectively set to be 300℃, 320 ℃, 350℃ and 270℃. Afterwards, identify the optimal process parameters in this work.

RESULTS AND DISCUSSION

Effect of reaction time on denitration efficiency

The effect of reaction time on denitration efficiency was studied in five experiments. Schematic diagram effect of reaction time on denitration efficiency, were drawn using those five-group experimental data, as shown in Figure 2. Five curves were plotted under NH_3/NO mole ratio 1.2 and under five different reaction temperatures. As seen in Figure 2, under reaction temperature 270℃ denitration efficiencies' change area were from 31.2% to 40.5% when reaction time from 5 min to 20 min. The denitration efficiency first increased and then decreased, finally form a parabola. Under the reaction temperatures 290℃, 300℃, 320℃, and 350℃ observing other four curves parabolas form also were found similarly. Besides, there existed optimal operational temperature. When reaction time was 14min, these five curves could reach the maximal values, in which 91.6% denitration efficiency value of the highest point at 320℃ could be reached.

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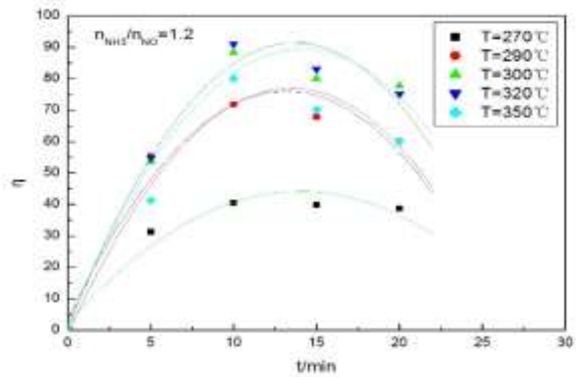

Figure 2 Effect of reaction time on denitration efficiency

Effect of reaction temperature and of NH_3/NO mole ratio on denitration efficiency

Effect curves of reaction temperature on denitration efficiency were plotted when NH_3/NO mole ratio was variable parameter, as shown in Figure 3. Under the condition of NH_3/NO mole ratio 0.8, the denitration efficiency was respectively 35.1%, 36.2 %, 41.3%, 39.3%, and 33.8% at reaction temperature 270℃, 290℃, 300℃, 320℃, and 350℃. From the view of the tendency, the denitration efficiency first increased and later decreased with the increase of reaction temperature, finally formed a parabola. Besides, four parabolic curves similarly could be achieved under the conditions of NH_3/NO mole ratio 1.0, 1.2, 1.4, and 1.6. With the increase of NH_3/NO mole ratio the denitration efficiency also increased. But the denitration results did not turn better and better with the increase of NH_3/NO mole ratio. Moreover, in the change intervals of those NH_3/NO mole ratio there existed an optimized value, 1.2. After maximal values of those denitration efficiency were compared the data results showed that 91.6% denitration efficiency, the highest value in experiments, could be gotten at NH_3/NO mole ratio 1.2.

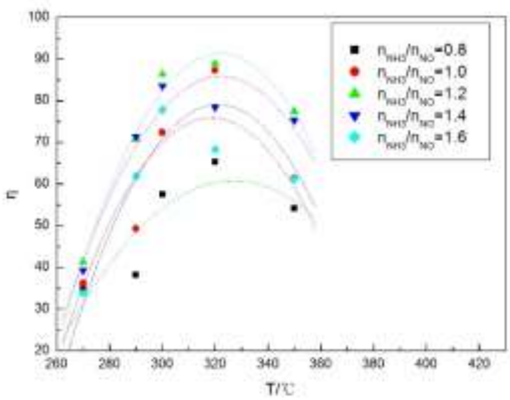

Figure 3 Effect of reaction temperature and of NH_3/NO mole ratio on denitration efficiency

Conclusions

Experimental results of sequence heating reaction between nitric oxide and ammonia showed that denitration efficiencies had been developed to become a parabola with the change of reaction time under a certain NH_3/NO mole ratio and under a certain temperature and that denitration efficiencies also had changed to become a parabola with the increase of the reaction temperature when a NH_3/NO mole ratio was identified. Under the optimal NH_3/NO mole ratio, 1.2, optimal reaction temperature, 320℃, and reaction time 14min 91.6% denitration efficiencies could be reached in this work.

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REFERENCES

[1] P. Pu, X. Liu, Y. Peng, X.Ren , and H. Zhou , “Effect of additive (C_2H_4, NH_3) addition on denitrification effect of AC/DC streamer discharge plasma”, Chinese Journal of Environmental Engineering, Volume 11, Issue 1, Pages 483-489, 2017.

[2] X.-H Ding, Z.-L Zhao, S. Chang, and H.-B Li, “Application of bio-mass fuels in the denitration of coal-fired boilers”, Journal of Engineering for Thermal Energy and Power, Volume 28, Issue 3, Pages 223-228, 2013.

[3] L. Pan, P. Yang, and Y. Cao, “Simulated calculation and optimization of internal flow field of selective catalytic reduction denitrification reactor”, Chinese Journal of Environmental Engineering, Volume 9, Issue 6, Pages 2918-2924, 2015.

[4] H. Xie, “Application of denitrification additive for reduction of NO, in NO_x regenerator flue gas”, Petroleum Processing and Petrochemicals, Volume 45, Issue 6, Pages 59-62, 2014.

[5] F. Wang, T. Chen, M. Jin, and P. Lü, “Simultaneous desulfurization and denitrification from flue gas using Urea/Piperazine solution”, Advanced Materials Research, Volume 881-883, Pages 641-644, 2014.

[6] J. Fan, H. Min, Y. Sun, Z. Zhang, X. Ran, and W. Teng, “Research and application of a Selective Catalytic Reduction(SCR) Unit for high temperature NO_x exhaust gas from CBM power plants”, Natural Gas Industry, Volume 35, Issue 3, Pages 115-119, 2015.

[7] D. Yang, and Q.-W Chen, “The discharge status and technical analysis of NO_x of thermal power plant boiler”, Applied Mechanics and Materials, Volume 535, Pages 131-134, 2014.

[8] Y. Xu, Y. Zhang, J. Wang, and J.Yuan, “Application of CFD in the optimal design of a SCR-$DeNO_x$ system for a 300MW coal-fired power plant”, Computers and Chemical Engineering, Volume 49, Pages 50-60, 2013.

[9] A. Klimanek, W. Adamczyk, A. Katelbach-Woźniak,G.Węcel, and A. Szlęk, “Towards a hybrid Eulerian-Lagrangian CFD modeling of coal gasification in a circulating fluidized bed reactor”, Fuel, Volume 152, Pages 131-137, 2015.

[10] J. Urech, L. Tock , T. Harkin, A. Hoadly, and F. Maréchal, “An assessment of different solvent-based capture technologies within an IGCC-CCS power plant”, Energy, Volume 64, Pages 268-276, 2014.

[11] Y. Wang, J. Wang, S. Guo, J. Lv, and Q. Gao, “Dynamic modelling and simulation study of Texaco gasifier in an IGCC process”, ICAC 2013 - Proceedings of the 19th International Conference on Automation and Computing: Future Energy and Automation, pages 246-251, 2013.

[12] S.-L Fu, Q. Song, and Q. Yao, “Study on the catalysis of $CaCO_3$ in the SNCR $deNO_x$ process for cement kilns”, Chemical Engineering Journal, Volume 262, Pages 9-17, 2015.

[13] B. Farcy, A. Abou-Taouk, L. Vervisch, P. Domingo, and N. Perret, “Two approaches of chemistry downsizing for simulating selective non catalytic reduction $DeNO_x$ process” , Fuel, Volume 118, Pages 291-299, 2014.

[14] T. Zhu, D. Li, Q. Fang, and G. Chen, “Flow field optimization for SCR system of coal-fired power plants”, Journal of Chinese Society of Power Engineering, Volume 35, Issue 6, Pages 481-488 and 508, 2015.

[15] Y. Zhao, R. Hao, P. Zhang, and S. Zhou “Integrative process for simultaneous removal of SO_2 and NO utilizing a vaporized $H_2O_2/Na_2S_2O_8$”, Energy and Fuels, Volume 28, Issue 10, Pages 6502-6510, 2014.

[16] K. Jastrząb, “Changes of activated coke properties in cyclic adsorption treatment of flue gases”, Fuel Processing Technology, Volume 104, Pages 371-377, 2012.

[17] Q. Ma , Z. Wang， F. Lin， M. Kuang， R. Whiddon， Y. He， and J. Liu, “Characteristics of O_3 Oxidation for Simultaneous Desulfurization and Denitration with Limestone-Gypsum Wet Scrubbing: Application in a Carbon Black Drying Kiln Furnace”, Energy and Fuels, Volume 30, Issue 3, Pages 2302-2308, 2016.

[18] H. Liu, X. Yu, and H. Yang. “The integrated photocatalytic removal of SO_2 and NO using Cu doped titanium dioxide supported by multi-walled carbon nanotubes”, Chemical Engineering Journal, Volume 243, Pages 465-472, 2014.

[19] H. Liu, H. Wu, J. Bao, X. Yu, and H. Yang , “Photochemical removal of NO and SO_2 from flue gas using UV irradiation”, Asia-Pacific Journal of Chemical Engineering, Volume 9, Issue 5, Pages 775-781, 2014.

[20] J.-J Yang, M. Qiang, J.-J Lei, W. Li , and X. Wang , “Removal of NO in flue gas with nano V_2O_5/AC catalyst”, Chemical Engineering(China), Volume 42, Issue 10, Pages 6-10 and 24, 2014.

[21] Z. Zhong, X. Zhang, B. Yang, J. Yao, "Effects of potassium, sodium, zinc and phosphorus on flue gas de-NO_x performance over V_2O_5/TiO_2 catalysts", Journal of Southeast University, Volume 43, Issue 3, Pages 548-552, 2013.
[22] W. Xie , D.-M Liang, Z.-C Sun , L.-T Li, Y.-G Wang, and Z.-G Xu, "Evolution and effects of surface chemistry of activated coke during combined SO_2/NO_x removal process", Journal of China University of Mining and Technology, Volume 40, Issue 3, Pages 448-452+463, 2011
[23] Q. Zhao, L. Sun, J.-M Shi, Q.-D Yin, S. Hu, and J. Xiang, "Study on synthesis of $CuO/\gamma\text{-}Al_2O_3$ catalyst via sol-gel method and its reduction of NO in flue gas", Power Engineering, Volume 28, Issue 4, Pages 620-624+646, 2008.
[24] Z. Han , J. Yu, S. Yang , X. Pan , and Z. Yan, "Application of electrolyzed seawater for NO removal from simulated marine diesel engine exhaust gas", Research of Environmental Sciences, Volume 30, Issue 1, Pages 144-151, 2017