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Study on ammonia injection and mixed element of SCR denitrification system

Yiqing Sun*, Xiuru Liu, Fangming Xue, Jingcheng Su, Feng Chen

Huadian Electric Power Research Institute Co., Ltd. Beijing branch, Beijing, China

*Corresponding author e-mail: yiqing-sun@chder.com

Abstract. Selective Catalytic Reduction (SCR) denitrification is the most widely used flue gas denitrification technology for coal-fired power plants due to its excellent comprehensive performance. The key to the denitrification efficiency is the uniform mixing of the reducing agents NH_3 and NO_x in the flue gas. In this paper, the linear controlled ammonia injection grid, partition-controlled ammonia injection grid and mixed element of type ammonia injection grid are compared. The advantages and disadvantages of various gas flow field uniformity adjustment techniques are analysed. It is pointed out that the mixed element of type ammonia injection grid technology is the main direction of the current ammonia injection technology development. Finally, the future development trend of the ammonia injection mixing device is pointed out.

Key words: flue gas denitrification; selective catalytic reduction; static mixer; ammonia injection grid.

1. Introduction

Nitrogen oxide (NO_x) is one of the main compositions in air pollution, which is dominated by combustion of fossil fuels. By 2014, thermal coal consumption accounted for about 51.7% of China's total coal consumption. In order to decrease of the emission of NO_x , China government has put forward the ultra-low emission plan for coal-fired power plants, which clarified that emission limits of dust, sulfur dioxide (SO_2) and NO_x are below 10 mg/m³, 35 mg/m³, and 50 mg/m³, respectively.

The dominant denitrification technology in industry includes flue gas denitrification process and low-nitrogen combustion process. Low-nitrogen combustion technology is based on reducing the generation of NO_x in the combustion process, while flue gas denitrification process is the flue gas removal NO_x technology after combustion. Flue gas denitrification process can be divided into selective non-catalytic reduction (SNCR) and selective catalytic reduction process (SCR). Ammonia selective catalytic reduction process (NH_3 -SCR) is widely used in coal-fired power plant to control the NO_x emissions, for its excellent comprehensive performance.

In this paper, the mechanism of SCR denitrification process and the evaluation index of gas mixture are briefly described. On this basis, NH_3 injection mixing technologies, such as linear controlled injection grid, partition controlled ammonia injection grid and mixed element of type ammonia injection grid, are summarized and analyzed. The research progress and the development trend of ammonia injection mixing technology are discussed.



2. Basic principles and evaluation indicators of NH₃-SCR

Although the removal efficiency of NO_x by SCR can be in the range of 70% to 90%, this process also produces ammonia slip. The key to its process design is the uniform mixing of reducing agent NH₃ and NO_x in flue gas. The design of the ammonia injection mixing system has a significant impact on the actual operation effect of the denitrification system: the NO_x and NH₃ in the inlet section of the catalyst in the SCR denitrification system are mixed unevenly, which will inevitably result in the shortage or excessive reductant in the local area; The insufficiency of reducing agent will lead to the decrease of efficiency of denitrification system. If the reductant is too much, ammonia slip will increase, which will lead to corrosion and blockage of the downstream air preheater.

Therefore, rational design of ammonia injection system to ensure the uniform mixing of NO_x and NH₃ in flue gas is the most important task in SCR engineering design. All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office.

2.1. Basic principles of NH₃-SCR

NH₃-SCR is a process that converts NO_x by heterogeneous catalyst into diatomic nitrogen and water, using ammonia (NH₃) as the reductant. NH₃-SCR flue gas denitrification system is mainly composed of an ammonia storage, SCR catalytic reactor, evaporation and injection by mean of a distribution grid.

The reduction reaction of NO_x takes place at SCR catalytic reactor and the chemical equation for NH₃-SCR is:



This reaction also bring about several secondary reactions:



2.2. Evaluation indicators of NH₃-SCR

Denitrification efficiency and NH₃ escape rate are two primary performance indicators of NH₃-SCR technology. Studies have shown that the uniformity of mixed gas in the cross-section of SCR reactor has a great influence on the denitrification efficiency of NH₃-SCR. The uniformity of the mixed gas depends on velocity uniformity and distribution of the uniformity of ammonia. The mixing degree of NH₃ and flue gas directly affects the denitrification efficiency, and also determines the escape rate of ammonia. Therefore the design of the ammonia injection mixing system has a significant impact on the actual operation effect of the denitrification system: the NO_x and NH₃ in the inlet section of the catalyst in the SCR denitrification system are mixed unevenly, which will inevitably result in the shortage or excessive reductant in the local area. The insufficiency of reducing agent will lead to the decrease of efficiency of denitrification system. If the reductant is too much, ammonia slip will increase, which will lead to corrosion and blockage of the downstream air preheater.

Therefore, rational design of ammonia injection system to ensure the uniform mixing of NO_x and NH₃ in flue gas is the most important task in SCR engineering design. At present, the main NH₃ injection mixing technologies includes linear controlled injection grid, partition controlled ammonia injection

grid and mixed element of type ammonia injection grid. The research and optimization of ammonia injection mixing technologies have become a research hotspot in recent years.

3. Ammonia injection mixing technology

NH₃ injection mixing device is commonly referred as ammonia injection grid (AIG). Its functions include injecting NH₃ into the flue gas and the mixing NH₃ with NO_x uniformly. The linear controlled injection grid, partition controlled ammonia injection grid and mixed element of type ammonia injection grid are briefly reviewed.

3.1. The linear controlled AIG

Linear controlled AIG is the most traditional ammonia injection method. It is composed of a parent pipe section for NH₃ and multiple branch pipe sections [1]. The nozzle is connected with the distribution pipe and connecting pipe. The ammonia supply quantity can be independently adjusted to match the NO_x in the flue gas.

The main advantages of linear controlled AIG are simple structure and small pressure drop. At the same time, it is low cost and simple operation. The disadvantage is that this technology can only adjust the branch pipe flow. Therefore, it is unable to adapt to the nonuniform distribution of NO_x in flue gas, and is highly dependent on the flue deflector. In addition, it is easy to be blocked due to the huge number and small diameter of AIG nozzles, resulting in nonuniform ammonia spraying.

3.2. Partition controlled AIG

Partition controlled AIG is an improved linear controlled ammonia injection grid. According to the flue conditions, the flue section is divided into 20 to 30 areas, and the quantity of NH₃ flow of each area can be adjusted separately. Therefore, an appropriate amount of NH₃ can be sprayed in each region to match the distribution of NO_x in flue gas.

This partition-controlled AIG device is suitable for the conditions of large cross-sectional area of flue and seriously uneven distribution of NO_x concentration [2]. Although partition controlled AIG overcomes the disadvantage of lack adjustability of linear control of ammonia injection grid, it has complex control, strong system linkage and high operational requirements. The control system of this technology is complex and requires strong linkage of the system. At the same time, this technology does not solve the drawback of traditional linear controlled AIG technology. For example, the partition controlled AIG technology also uses huge small nozzles, which is easy to be blocked, leading to the non-uniform ammonia injection.

3.3. Static mixed element of type AIG

Static mixed element of type AIG technology is used in combination with static mixer. Several to dozens of nozzles are generally arranged in the flue section, and more static mixers are arranged in the downstream of the ammonia injection pipe [3]. The NH₃ nozzles and the spoiler blades of the mixer are arranged correspondingly, and the mixed gas of NH₃ and NO_x forms a stable eddy current or swirl under the induction of the mixing element, so as to strengthen disturbance and enhance turbulent diffusion[4].

Static mixed element of type AIG technology uses large diameter nozzles, which is less prone to blockage. Furthermore, it also has good operational flexibility and good system integration. Furthermore, it has good operational flexibility and comprehensive effect. The main disadvantages are that the static mixer has a complicated structure, a large pressure drop, and a long mixing distance of the flue gas. The main disadvantage of this technique is the complex structure of the static mixers, resulting in a large pressure drop and a long gas mixing distance.[5]

Owing to the severe peak load regulation, the use of traditional AIG technology is prone to nozzle blockage, resulting in the increase of ammonia escape and the serious blockage of air preheater. Comprehensive analysis of the above technologies, the static mixed element of type AIG technology is the future mainstream direction of SCR AIG technology used in coal-fired power plants. It has the best

comprehensive performance, high mixing efficiency, simple structure, stable operation and large flexibility.

The main reason for limiting the application of static mixers in coal-fired power plants is that static mixers results in high pressure drop and requires sufficient mixing distance. Old power plants with small space distances are difficult to meet the static mixer layout requirements. Therefore, the development of low-pressure drop static mixers is the focus of R&D in the future.

4. Conclusion

The uniformity of the mixed gas flow field at the catalyst layer of the SCR reactor is an important factor in the efficient flue gas denitrification.[6] It is difficult to optimize the uniformity of the gas flow field in how to reduce the concentration unevenness coefficient as much as possible.[7] According to the principles, characteristics and current problems of the above-mentioned various mainstream technologies, it is considered that the ammonia spray mixing device should be developed in the following directions.

- (1) Under the condition that the mixing uniformity index meets the engineering requirements, the static mixed element of type AIG has the best comprehensive performance, followed by the partition-controlled AIG and the linear controlled AIG.
- (2) Develop static mixers with high mixing efficiency, simple structure and stable operation; reduce construction investment, operation and management costs, and improve operational flexibility.
- (3) Coordinated to improve the speed deviation and concentration deviation upper limit of the mixed gas at the catalyst layer of the reactor, focusing on reducing the NH₃ concentration unevenness coefficient.
- (4) Introduce modern control theory, accurately and economically control the amount of ammonia sprayed according to the value of export NO_x; enhance the jet effect on the basis of the original design, and improve the positioning level of the ammonia pipe.

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