Optimization of Flow Field and Nox Concentration Field of Denitrification System in Coal-Fired Power Plant

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Abstract. A unit of a coal-fired power plant in North China was selected to study. The flow field distribution and NOx concentration distribution at the inlet and outlet of the denitrification system are tested. Then, the flow field adjustment and optimization of the unit are carried out based on the above test results, and the verification test of optimized flow field and NOx concentration distribution are carried out. After the flue optimization, the uniformity of NOx concentration distribution at SCR reactor inlet and outlet was improved, and the flue rate at SCR reactor inlet need further optimization through combustion adjustment.

1. Introduction
With the increasing attention to environmental protection in China, people pay more attention to the pollutants emission from coal-fired power plants [1-2]. In order to further reduce the emission of atmospheric pollutants from coal-fired power plants, the “provincial plan of action for energy conservation and emission reduction of coal-fired power plants (2014-2020)” issued in September 2014 requires that the emission limit of nitrogen oxides (NOx) for key areas and newly built coal-fired generating units was 50 mg/m³ [3]. The implementation of “Environmental protection tax law of China” on January 1, 2018 stipulated that the emission concentration of air pollutant below the standard 50% cut tax in half [4]. That is to say, when the emission concentration of NOx reaches 25mg/m³, the environmental protection tax will be reduced by half. Therefore, it is of great economic and practical significance to explore and optimize the denitrification capacity of the existing denitrification system to reach the 50% of the existing standard.

This paper chooses a unit of a coal-fired power plant in North China to study. The denitrification system of the unit is tested, and the flow field distribution, NOx concentration distribution at the inlet and outlet of the denitrification system and its influence on NOx control are evaluated. Then, the flow field adjustment and optimization of the unit are guided, and the test of optimized flow field and NOx concentration distribution of NOx are carried out. Through the optimization and adjustment of flue, this paper provides a basis for improving the denitrification capacity of the unit meeting the 50% of the existing NOx emission standard.
2. Experiment and method

2.1. Flue gas denitrification system
The flue gas denitrification system (Selective catalytic reduction, SCR) of selected power plant is described as follows: flue gas is extracted from the outlet flue of economizer, and enters the SCR reactor through horizontal flue, vertical flue, top of reactor and rectifying grid. There are five groups of diversion plates in the original denitrification system. The first group of diversion plates is located at the inlet of the horizontal flue enlargement section, the second group is located at the outlet of the horizontal flue enlargement section, the third group is located in the lower elbow of the vertical flue, the fourth group is located in the upper elbow of the vertical flue, and the fifth group is located in the upper elbow of the vertical flue.

![Flue design of SCR reactor.](image)

2.2. Test scheme
The NOx concentration, temperature and flue gas velocity at inlet and outlet of SCR reactor before and after modification were measured. The flue gas NOx was measured by flue gas analyzer (NOVA 4000), and the flue gas temperature was measured by thermocouple and electronic thermometer. The flue gas dynamic pressure was measured by micro-pressure gauge and Pitot tube according to grid method, and the flue gas velocity is calculated via values of flue gas dynamic pressure and temperature [5].

3. Results and discussions

3.1. Pre-modification testing
The test results of flue gas velocity and NOx concentration at the inlet and outlet of SCR reactor are shown in Table 1.

| Side | Average Velocity (m/s) | RSD (%) |
|------|------------------------|---------|
| A    | 11.8                   | 19.99   |
| B    | 11.8                   | 14.21   |

The average flue gas velocity at the inlet of SCR reactor is 11.8 m/s for both sides (A and B), and the flue gas velocity at the far side of SCR reactor is lower than that near the furnace side. The distribution relative standard deviations (RSD) of gas velocity on A and B sides of SCR reactor inlet were 19.99% and 14.21% respectively. The required maximum RSD of flue gas velocity at SCR inlet section was 15% [6], and the distribution uniformity of flow velocity was not satisfied in a side.
The average NOx concentration at the A side and B side of SCR reactor inlet were 129.9 mg/m³ (standard state, dry base, 6% O₂) and 106.2 mg/m³ (standard state, dry base, 6% O₂), respectively. The distribution RSD of NOx concentration on A and B sides were 58.84% and 66.24% respectively, and the distribution deviation was large which mainly reflect the NOx concentration at the near furnace side of both sides are larger than those at the far furnace side.

The average NOx concentration at the A side and B side of SCR reactor outlet were 48.7 mg/m³ (standard state, dry base, 6% O₂) and 17.8 mg/m³ (standard state, dry base, 6% O₂), respectively, showing a larger concentration difference between two sides. The distribution RSD of NOx concentration on A and B sides of SCR reactor outlet were 23.36% and 47.33%, respectively, and the deviations of NOx concentration distribution on both sides were different.

Table 1. The NOx concentration and flow rate at the inlet and outlet of SCR reactor before modification.

3.2. Reform scheme
The pre-modification experimental results showed that the distribution of NOx concentration flow fields in the both sides of SCR reactor inlet were not uniform, so the diversion and equalization of flue should be adjusted first; the distribution of NOx concentration at the outlets of A and B sides were not
uniform also, and the catalytic performance of catalysts should be checked while adjusting the flow fields of SCR reactor. Combining with the structure of the reactor, the optimization scheme of the mixed flow field is as follows:

1) The length of the horizontal straight section of the second diversion plate group was reduced to 350 mm; the number of diversion plates in 3 m was increased to 11, and the distance between diversion plates was 250 mm; the number of diversion plates in 9.2 m was increased to 23, and the distance between them was 383.3 mm.

2) The length of the horizontal straight section of the fourth diversion plate group was reduced to 500 mm.

3) The number of the fifth group of diversion plates was added to 7 along the height direction, and the diversion plate spacing was 400 mm.

4) The first group of mixers was installed before the expansion joints of the horizontal flue, and the second group of mixers was installed at the vertical flue.

3.3. Revamping effect of SCR reactor
After modification, the NOx concentration and flow rate at the inlet and outlet of SCR reactor are also detected, as shown in Table 2.

Table 2. The NOx concentration and flow rate at the inlet and outlet of SCR reactor after modification.
The distribution RSD of NOx concentration on A and B sides of SCR reactor inlet were 2.54 % and 4.06 % respectively, which decreased from the distribution RSD of 65.8 % and 73.88 % of pre-modification test. The uniformity of NOx concentration distribution at SCR reactor inlet was improved.

The distribution RSD of flow velocity on A and B sides of SCR reactor inlet were 16.76% and 22.13 % respectively, which present different improvement results compared with the distribution RSD of pre-modification test. The uniformity of flow field at the inlet of a side was improved and B side was deteriorated, but the change of both sides was not significant, which need further optimization through combustion adjustment.

The distribution RSD of NOx concentration on A and B sides of SCR reactor outlet were 7.42 % and 9.14 % respectively, which decreased from the distribution RSD of 21.05% and 29.63% of pre-modification test. The uniformity of NOx concentration distribution at SCR reactor outlet was improved.

4. Conclusion

The distribution RSD of NOx concentration on A and B sides of SCR reactor inlet decreased from 65.8 % to 2.54 % and from 73.88 % to 4.06 % respectively after optimization.

The distribution RSD of NOx concentration on A and B sides of SCR reactor outlet decreased from 21.05 % to 7.42 % and from 29.63 % to 9.14 % respectively after optimization.

The uniformity of flow field at the inlet of a side was improved and B side was deteriorated, but the change of both sides was not significant after optimization, which need further optimization through combustion adjustment.

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