Technology Research and Application on Catalyst Entire Life-cycle Management of Coal Fired Power Plant

Yang Zhang\textsuperscript{1,2}, Qianwei Feng\textsuperscript{1}, Sha Li\textsuperscript{1}, Cunwen Li\textsuperscript{1}, Yukun Pei\textsuperscript{1} and Yue Zhu\textsuperscript{1}

\textsuperscript{1}Huadian Electric Power Research Institute Co. Ltd., Hangzhou 310030, China
\textsuperscript{2}State Key Laboratory of Clean Energy Utilization, Zhejiang University, Hangzhou 310027, China
cola1860@@foxmail.com

Abstract. Along with the comprehensive promotion of flue gas ultra-low emission reconstruction in coal-fired power plants, the stability, reliability and economic efficiency of SCR denitrification facility have emerged. SCR catalyst entire life-cycle management is the key to solving the problem. Given the present situation of the catalyst market, operation and maintenance, third-party service, a SCR catalyst entire life-cycle management technology have been proposed, including catalyst supply, quality control, operation and maintenance, effect optimization, life management and scrap disposal in the entire life-cycle of catalyst. By clarifying the accountability units at different stages, implementing corresponding quality control, operation and maintenance and evaluation and optimization technology, demonstration application suggest that the management technology could give full play to the professional expertise of participant companies, make the denitrification facility stable, reliable and economical, and bring obvious environmental and economic benefit.

1. Introduction
Since the 12th Five-Year Plan of China, large-scale denitrification and ultra-low emission renovation have been carried out in coal-fired power plants, among which SCR denitrification technology is the most widely used \cite{1}. However, due to the centralized transformation task, lack of technical experience, inadequate quality control of major equipment, uneven quality of denitrification catalyst, and insufficient operation and maintenance experience of power generation enterprises, some hidden problems have gradually emerged after commissioning, such as catalyst wear, serious ash blocking, uneven distribution of flow field, performance indicators cannot reach the design value, air pre-heater blockage and corrosion are common problems \cite{2}. In the current situation of coal-fired power plants promoting ultra-low emissions in an all-round way, higher requirements are put forward for the operation stability, reliability and economy of SCR denitrification unit. The key is to control the catalyst, which is the core of SCR denitrification.

Developed countries have experienced more than 40 years of industrial application of SCR denitrification technology. In view of many problems faced by SCR denitrification in the long-term operation process, a set of advanced and mature life-cycle management mode has been established \cite{3-7}. However, compared with foreign countries, the quality of power coal in China is quite different, the supply of coal is unstable, the operation load is changeable, the operation mode and operation parameters of units are quite different, and the catalyst market has changed greatly in recent years, and the products
are uneven. Therefore, it is not the best choice to apply foreign technology mechanically. Power generation groups, industrial companies and scientific research institutes have carried out a series of exploratory work in catalyst procurement and quality control, but the research and application of catalyst life-cycle management technology is still in its infancy, and mainly focus on guiding the operation and management of catalyst through third-party catalyst detection and life assessment [8-12]. Aiming at the problems existing in the application of denitrification catalyst, based on a lot of investigation and analysis, the technology of catalyst life-cycle management adapted to the present situation of denitrification application in China is studied and applied, and the product supply, quality control, efficient operation and maintenance, efficiency improvement optimization, life management and scrap disposal covering the whole life-cycle of catalyst are put forward. The life-cycle management model has been demonstrated and applied on a 1000MW unit, which can be used for reference and further discussion in the follow-up work.

2. Product Supply
Because the unit involves the transformation of ultra-low emission, the catalyst manufacturer is responsible for the supply of 404.8m3 catalyst with an additional layer, guarantees the performance of the catalyst throughout its chemical life cycle, replaces the damaged catalyst free of charge during operation, and disposes harmlessly of the spent catalyst with the same amount of loading after the expiration of the chemical life of the catalyst. Power generation enterprises adopt the payment method of 6:2:2 ratios in the chemical life of catalyst, and give the reward of 150,000 yuan/1000 h to the catalyst manufacturer after the catalyst life exceeds its life, which provides effective guarantee for the quality of catalyst supply.

3. Quality Control
Before the installation of the newly purchased catalyst, the third party technical service unit is responsible for sampling and testing the catalyst and evaluating the quality of the catalyst. As shown in table 1, the physical and chemical properties and process characteristics of the catalyst were tested by the third party technical service unit, and the comprehensive quality of the catalyst was evaluated according to the evaluation method agreed by the three parties [10]. The results showed that although some of the indicators were deviated from the reference values, the comprehensive quality of the catalyst could meet the requirements of use. At the same time, the test results were included in the database of catalyst performance parameters of the unit, which served as the basic parameters for the subsequent development of catalyst life management.

Table 1. Testing and evaluation results of new catalyst.

| Category               | Unit          | Standard score | Reference value | Test value | Scoring method                                                                 | Score |
|------------------------|---------------|----------------|-----------------|------------|---------------------------------------------------------------------------------|-------|
| MoO3                   | %             | 10             | 3               | 3.21       | 1 point will be deducted for every 0.1% lower                                    | 10    |
| V2O5                   | %             | 10             | 3               | 1.33       | 2 points will be deducted for each 0.5% increase                                  | 10    |
| SiO2                   | %             | 5              | 6               | 7.06       | 1 point will be deducted for every 1%                                            | 3.9   |
| Al2O3                  | %             | 5              | 2               | 1.95       | 1 point will be deducted for every 1% increase                                    | 5     |
| SA                     | m²/g          | 5              | 70              | 95.5       | 1 point will be deducted for every 2m²/g increase                                 | 5     |
| Adhesion strength      | %             | 20             | 2.0             | 2.16       | Level 1 is 20; Level 2 is 10; Level 3 is 5; Level 4 is 2; Level 5 is 0.          | 2     |
| Wear strength          | mg/100U       | 30             | 130             | 112        | 1 point will be deducted for every 1mg/100U increase                             | 30    |
| Wear strength          | %             | 10             | 89.1            | 89.3       | Level 1 is 20; Level 2 is 10; Level 3 is 5; Level 4 is 2; Level 5 is 0.          | 2     |
| NH3 slip concentration | mg/m²        | 10             | 2.28            | 1.29       | 3 point will be deducted for every 0.5% lower                                    | 10    |
| SO2/SO3 conversion rate| %             | 5              | 1               | 0.84       | 1 point will be deducted for every 0.05μL/L increase                             | 5     |
| Synthesis score        |               |                |                 |            |                                                                                  | 80.9  |
4. Efficient Operation and Maintenance
Based on the operation and maintenance instructions of the catalyst manufacturer and the technical consultation of the third party technical service unit, the operation and maintenance personnel of the 1000MW unit strictly control the inlet flue gas parameters such as NOx concentration and dust concentration in their daily operation within the design scope, ensure the on-line instrumentation in a healthy state, and clean up the ash in time when the unit shuts down. Operators focus on the range of operating parameters such as NOx concentration, denitrification efficiency, ammonia injection rate, ammonia slip, flue gas temperature, catalyst pressure difference and air preheater pressure difference at the inlet and outlet of denitrification reactor, and deal with the abnormal parameters in time. Maintenance personnel focus on common problems of denitrification devices, such as blockage of ammonia supply valve, poor regulation performance, blockage of ammonia injection nozzle, deformation of diversion plate and rectifier device, deformation and failure of catalyst seals, ash accumulation and abrasion of catalyst, etc., and deal with them in time. Through the above efficient operation and maintenance work, the denitrification plant can be ensured to operate in a healthy and efficient state.

5. Efficiency Improvement and Optimization
In the process of ultra-low emission renovation of the 1000MW unit, the third-party technical service unit puts forward the renovation plan according to the present situation of denitrification unit. The catalyst manufacturer is responsible for the supply and performance assurance of 404.8m³ loaded catalyst. The module with serious wear and tear in the initial two-layer catalyst is replaced synchronously. The flow field is simulated and checked, and the top guide plate of the reactor is partial adjusted. As shown in table 2, the performance test results carried out by the third party technical service units after the transformation show that all performance indicators have reached the guaranteed value.

| Category                   | Unit       | Guaranteed value | Test result | Remarks |
|----------------------------|------------|------------------|-------------|---------|
| Flue gas volume            | m³/h       | 3292467          | 3279829     |         |
| Inlet flue gas temperature | ℃          | 356              | 372         |         |
| Inlet NOx concentration    | mg/m³      | 400              | 385         |         |
| Inlet dust concentration   | mg/m³      | 47000            | 30979       |         |
| Inlet SO₂ concentration   | mg/m³      | 28.8             | 24.1        |         |
| Flue gas temperature drop | ℃          | 3                | 2           | Qualified |
| Outlet NOx concentration  | mg/m³      | -                | 27          |         |
| Outlet SO₂ concentration  | mg/m³      | -                | 47.5        |         |
| NH₃ slip concentration    | mg/m³      | 2.28             | 1.59        | Qualified |
| Denitrification efficiency | %          | 87.5             | 89.8        | Qualified |
| SO₂/SO₃ Conversion Rate   | %          | 1.0              | 0.81        | Qualified |
| System resistance         | Pa         | 630              |             |         |
| A reactor                 | Pa         | 608              |             |         |
| Breactor                  | Pa         | 585              |             |         |

6. Life Management
After running for one year, the 1000MW unit has some problems, such as lower denitrification efficiency, higher ammonia slip concentration, blockage of air preheater, etc. However, regular catalyst performance tests show that the denitrification efficiency meets the performance guarantee value, the ammonia escape rate is 1.38mg/m³, and no abnormal attenuation of catalyst performance has been found. In order to solve this problem, the third party technical service unit carried out a performance evaluation and diagnosis test of the denitrification unit. According to the test results, the flow field of the
denitrification unit was judged to have bigger problems. On this basis, the optimization test of

denitrification and ammonia spraying was further carried out. As shown in figure 1, the non-uniformity

of NOx concentration distribution at reactor outlet decreased from 42.0% and 44.5% to 10.0% and

10.1%, denitrification efficiency increased from 85.8% to 89.1%, and ammonia escape concentration
decreased from 4.89 mg/m³ to 1.76 mg/m³, respectively. By carrying out the above work, the operation
status of the denitrification unit was adjusted in time, and the problems such as increased consumption
of denitrification ammonia and blockage of air preheater were solved, and the replacement of catalyst
in advance was avoided.

![Figure 1. NOx concentration at the SCR reactor outlet before and after the AIG optimization.](image)

On the premise of ensuring the denitrification efficiency, the catalyst life can be determined by testing
whether the ammonia escape concentration exceeds the performance guarantee value of 2.28mg/m³ [13].
As shown in figure 2, the catalyst test results and optimized test results show that the performance of
catalyst can meet the application requirements. If the life of catalyst is determined according to the pre-
optimization test results, the catalyst will be replaced in advance and the catalyst activity cannot be fully
utilized.

![Figure 2. Analysis of the catalyst testing and performance experiment results.](image)

7. Scrap Disposal

When the 1000MW unit purchases catalyst, it is agreed that the scrap catalyst will be recycled and
disposed by the catalyst manufacturer. Considering that the catalyst purchased by the ultra-low emission
modification will continue to be in service after the expiration of chemical life, the catalyst manufacturer
is required to dispose of the catalyst with equal loading amount before replacing the catalyst [3, 4].

The demonstration application results of the above-mentioned 1000MW unit catalyst life-cycle
management show that the implementation of life-cycle management can effectively enhance the NOx
emission capacity, prolong the service life of the catalyst, reduce the disposal of scrap catalyst, reduce the energy consumption caused by the consumption of catalyst, and avoid the abnormal increase of operating resistance of denitrification unit and air preheater. The unit can reduce the accident, avoid the environmental risk caused by improper disposal of scrap catalyst, so it can produce significant environmental and economic benefits.

8. Conclusion
Under the current situation that coal-fired power units are pushing forward ultra-low emission and environmental protection facilities into the stage of fine operation and maintenance, the existing catalyst management mode cannot meet the requirements of operation stability, reliability and economy of SCR denitrification unit, so it is imperative to carry out the life-cycle management of denitrification catalyst. The life-cycle management of catalysts should not only ensure the intensive cost of catalyst procurement, but also include the efficient performance control of denitrification plants. On this basis, the reliable, efficient and economical operation of denitrification plants can be realized. Therefore, the life-cycle management model of catalysts should cover the product supply, quality control, efficient operation and maintenance, efficiency improvement, life management and scrap disposal of catalyst throughout its life cycle. The six parts are not only connected in series, but also integrated with each other. The catalyst manufacturer is responsible for the product supply, efficiency improvement and waste disposal of the catalyst throughout its life cycle. The third-party technical service unit provides the technical service of catalyst quality control and catalyst life management. The power generation enterprise concentrates on the operation and maintenance of denitrification, which can give full play to the professional expertise of all units and has strong operability, and can produce remarkable environmental protection benefits and economic benefits.

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