Study on High Temperature Ultra-clean Electrostatic-fabric Integrated Precipitator Technology and Its Application Prospect in Cement Industry

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Abstract:

The gas denitrification has always been the most difficult environmental problem in cement industry. High Temperature Ultra-Clean Electrostatic-Fabric Integrated Precipitator (EFIP for short) adopts the alloy fiber filter media, the service temperature can reach above 400℃, and the dust removal before denitrification can be realized by working with SCR. A pilot-scale test bench integrated technology of High Temperature Ultra-Clean EFIP and denitration has been built in a power plant, achieving the outlet dust concentration of less than 10mg/m^3 and the outlet NOx concentration of less than 50mg/m^3. Since the application of the High Temperature Ultra-Clean EFIP in the 1750t/d baking furnace of an aluminum plant, the dust concentration and the operating pressure drop has been kept below 5mg/m^3 and 500Pa respectively for a long term. This technology is very suitable for cement industry, which can realize the integration process of "high temperature dust removal + low dust denitration", and solve the difficulties of denitration in cement industry.

Key Words: High Temperature Ultra-Clean Electrostatic-Fabric Integrated Precipitator dust collection and denitrification integrated alloy fiber filter media cement industry ultra-low emission

0 Introduction

In recent years, due to the country's efforts to promote ultra-low emission in coal and power industry, EFIP technology has made great progress. Since the first EFIP was put into service in Shanghai Pudong Cement Plant in 2003, the installed capacity of EFIP in domestic coal-fired power plants has exceeded 250,000 MW during 16 years, and the emission concentration can achieve 10mg/Nm^3 or even 5mg/Nm^3. The

emission of EFIP is stable, and it is almost not affected by working conditions, ash ratio resistance, dust concentration and other factors. Compared with bag filter, the pressure drop is smaller, and it can be applied to high ash and high sulfur coal. These remarkable characteristics determine that it can be promoted and widely used.

At present, iron and steel, cement, chemical, non-ferrous and other non-electric industry environmental protection situation is still severe. The policy of ultra-low emission is gradually being spread from the power industry to the non-electric industry. However, due to the different products of non-electric industry, and the process routes are multifarious, so a single environmental protection product is difficult to cope with all production processes. For example, the emission of NOx has always been a key problem for the cement industry to achieve ultra-low emissions, and the reason lies in the high concentration of fly ash and NOx in the cement industry. When the low temperature SCR catalyst is not mature, the catalyst service life is very short if the high temperature and high dust SCR is used directly for denitrification. However, if other processes are used for denitrification, it is difficult to achieve ultra-low emission standards [1-3].

In view of the current difficulties faced by the cement industry, on the basis of the existing ultra-clean EFIP technology, the high-temperature ultra-clean EFIP technology has been successfully developed. This technology proposes that the high temperature ultra-clean EFIP is used to remove dust under situation of high temperature, and then SCR catalyst at the upper part of the clean gas chamber is used to remove denitration. In this paper, the pilot test results of this technology in a power plant and the application results in alumina industry are introduced, and the feasibility of its application in cement industry is discussed.

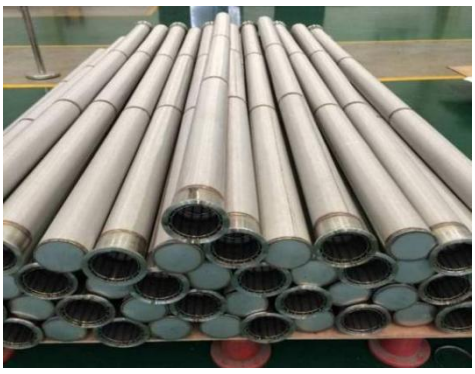
1 High-temperature Ultra-clean EFIP Technology

High temperature ultra-clean EFIP technology is a high temperature ultra-clean dust removal + low dust SCR denitration technology, which is the key high temperature dust removal technology in the new process of "dust first, denitration later". That is, the high temperature dust removal is carried out before SCR denitration. The precipitator adopts high temperature EFIP, which can remove almost all particles and

achieve ultra-low emissions. There is no need to set up secondary dust removal afterwards. At the same time, the problems of wear, blockage and poisoning caused by fly ash on catalyst are solved, operation and maintenance costs are reduced, and the service life of catalyst is greatly extended. High temperature dust removal + low dust denitration technology can significantly improve the reliability and stability of flue gas treatment device, and broaden the selection of environmental protection technology.

Alloy fiber filter media technology is the most subversive core technology of high temperature ultra-clean EFIP. Alloy fiber filter media is made of alloy fiber of micron wire diameter (material 316L, 310S, C276, iron chromium aluminum, etc.) through non-woven paving after sintering, which is characterized by high porosity, good air permeability, low filtration resistance, high filtration accuracy. Alloy fiber filter media was first used in aerospace industry because of its high preparation technology and high price. After civil use, it is mainly used for high temperature liquid filtration and chemical fiber melt filtration. Differ from traditional chemical fiber filter media, alloy fiber filter media is the biggest characteristic of high temperature and corrosion resistance, the use temperature is usually above 400℃ and up to 800℃, far higher than ordinary chemical fiber filter media (not more than 260℃).

Compared with ceramic and other high temperature filter medias, alloy fiber filter media has many advantages: 1) ultra-long filter bag service life (≥8 years); 2) Waste filter media can be recycled, without secondary pollution; 3) High filtration accuracy, high dust removal efficiency, can achieve ultra-low emission of particulate matter; 4) High temperature resistance (< 800℃); 5) High mechanical strength; 6) Good wear resistance; 7) Good heat impact strength; 8) Good toughness and processing performance (welding allowed, etc.).



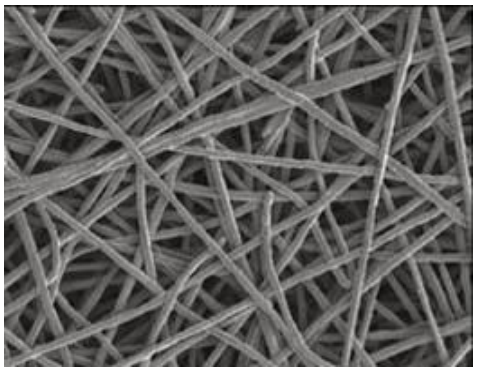


Fig. Appearance and microstructure of alloy fiber filter media

2 Results of Pilot Test

A pilot plant was set up near by a 1000MW unit of a power plant. High-temperature flue gas is led from the outlet of economizer of 1000MW unit to pilot plant, and the flue gas returns to original place after purification. In order to cope with high temperature flue gas, alloy fiber filter bag is used. In order to verify the reliability of low-dust denitration process, SCR catalyst was arranged in the upper part of the gas chamber for denitration, and the ammonia injection inlet was set at the entrance of the precipitator. The pilot plant is shown in Figure 2, and the process flow is shown in Figure 3.

Fig2 Image of pilot test bench

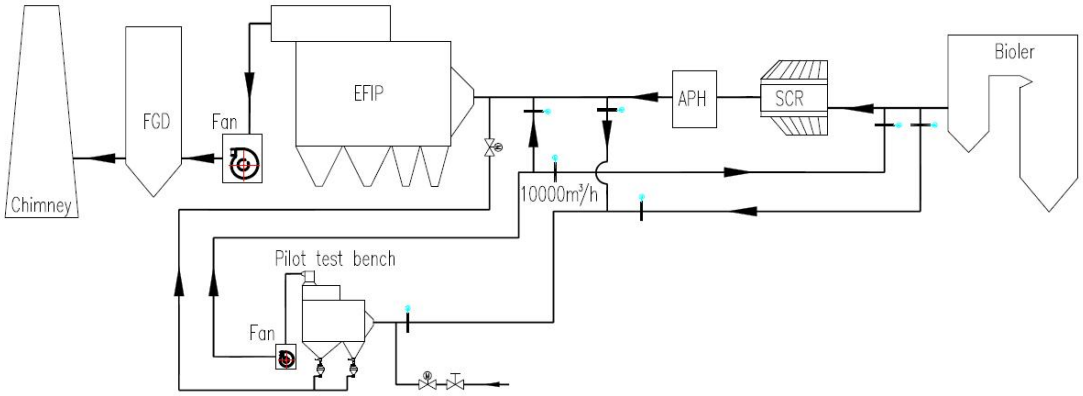


Fig3. Process flow chart of pilot test bench

The main technical indexes of the pilot-scale test bench for high temperature ultra-clean EFIP shows in Table 1.

Table 1 Design data of pilot-scale test bench of high temperature ultra-clean EFIP

No.	Items	Unit	Data
1	Inlet flue gas volume	m^3/h	8000~10000
2	Inlet flue gas tempt.	℃	350
3	Inlet dust concentration	g/m^3	30
4	Design pressure drop	Pa	6000
Electric field data			
1	Chamber No./partition no before and after the electric field		1/2
2	Access No.		4
3	Homopolar space	mm	400
4	Anode plate type/material	mm	BE/SPCC
5	Cathode wire type/material	m	Needled wire/stainless steel
6	Anodic vibration mode		Top electromagnetic hammer vibration
7	Cathode vibration mode		Top electromagnetic hammer vibration
8	HV power supply		0.02A/66kV
Bag zone data			
1	Filtration area	m^2	163
2	Filter bag material		316L
3	Continuous use tempt. allowed of filter bag	℃	400
4	Jet air source pressure	MPa	0.2~0.3

After the pilot plant was built and continuously operated with flue gas for 3 months under the high temperature condition of 350℃, the performance of precipitator was tested, of which the dust emission under three different air volumes was tested respectively. The results are shown in Table 2.

Table 2 Performance test data of pilot test bench

Test Conditions		1	2	3
Flue gas flow	m^3/h	11957	10514	8032
Inlet dust content	g/m^3	23.763	23.966	23.651
Outlet dust content	mg/m^3	9.8	7.5	4.8
Dust removal efficiency	%	99.959	99.969	99.980
Inlet NOx concentration	mg/m^3	197	205.7	201.5
Outlet NOx concentration	mg/m^3	48.3	48.7	46.9
NOx removal efficiency	%	75.5	76.3	76.7

As shown in Table 2, the flue gas flow at the inlet of the pilot test bench is about $10000m^3/h$, which meets the design requirements. The dust concentration at the inlet is about $24g/m^3$, and the NOx concentration at the inlet is about $200mg/m^3$, which are consistent with the flue gas characteristics of general thermal power plants. The outlet dust concentration and NOx concentration are less than $10mg/m^3$ and $50mg/m^3$ respectively, both of which can meet the requirements of ultra-low emission.

The above test results show that the high temperature ultra-clean EFIP can realize the new process of "dust removal first, denitrification later" of high temperature ultra-clean dust removal + low dust SCR denitrification. The stability of denitration system can be guaranteed synchronously while the dust removal emission reaches the standard. Moreover, it is feasible to arrange SCR on the top of the clean gas chamber for denitration. This arrangement can greatly save the floor space and steel structure, and can also greatly reduce the cost of denitration process.

3 Results of Engineering Application

An aluminum plant has 6 alumina baking furnaces, among which no.1 is out of service, no. 2 and no. 3 are all rated at 1350t/d, no. 4 is rated at 1700T /d, no. 5 and no.

6 are rated at 1750t/d. High temperature ultra-clean EFIP technology is adopted to improve the efficiency of dust removal system of no.5. Since it was put into operation in September 2019, three performance tests of high-temperature ultra-clean EFIP had been organized. The results of the three tests showed that the outlet emission concentration of particulate matter was less than 5mg/m^3, which was much better than the special emission limit requirements of air pollutants in the amendment to the *Emission Standard of Pollutants from Aluminum Industry* (GB25465-2010).

Due to the excellent performance of high temperature ultra-clean EFIP in alumina industry, as a mature new process, this technology has been widely recognized by alumina industry, and has been popularized and applied in alumina industry. Up to now, 21 sets have been installed and put into operation with stable and controllable outlet emissions.

4 Feasibility Analysis of Application of High Temperature Ultra-clean EFIP Technology in Cement Industry

Dust is known to have a significant impact on SCR operations. High dust concentration, uneven flow field distribution and other factors may cause physical blockage and wear of SCR catalyst [4]. The alkali metal, arsenic, phosphorus, lead and other chemical elements contained in dust can also cause chemical poisoning and inactivation [5~8]. Therefore, SCR has always been divided into two types of high-dust arrangement and low-dust arrangement. A large number of operation data shows that the operation and catalyst service life of low-dust SCR arranged in gas-fired units are obviously better than that of high-dust SCR arranged in coal-fired units. Therefore, flue gas purification has always been a systematic problem.

Removal of NOx from flue gas with high dust concentration has always been a difficult problem in cement industry. According to current emission standards, the NOx emission concentration limit is 400mg/Nm^3. If the cement industry will implement the ultra-low emission standard of 10mg/Nm^3 of dust and 50mg/m^3 of NOx in the future, the widely used SNCR and low nitrogen combustion technology will be bound to fail to meet the emission requirements. Once again, SCR will be the only viable option. Some cement kilns abroad have adopted SCR for denitrification, such as Solnhofen in Germany, Monselice in Italy, Joppa in the United States and

other cement plants have adopted SCR for NOx removal, but most of them adopt high dust arrangement, causing catalyst wear and poisoning during operation [9].

In order to solve the denitrification difficulties of cement industry, scholars at home and abroad have been trying to develop a new low-temperature SCR catalyst to carry out the process of low-temperature dust removal and then low-temperature denitrification [10,11]. However, due to cost, efficiency and other factors, no successful application of engineering cases have been reported at home and abroad.

High temperature SCR denitrification is a very mature denitrification technology at present. With the comprehensive promotion of ultra-low emissions in coal-fired power plants, SCR denitrification under 370℃ working conditions has been widely used in thermal power plants across the country. The only problem is how to remove the dust before high temperature denitrification, that is, to ensure the long-term stable and reliable operation of SCR denitrification. High temperature dust removal is a mature dust removal technology. As early as the 20th century, there were boilers abroad using high temperature dust removal method with SCR denitration. Show according to the data, the boilers of a number of power plants in Japan use high temperature ESP, the most representative of which is the 2×1000MW thermal power unit of Matsuura Thermal Power Plant of Kyushu Electric Power Company in Japan. Its high temperature ESP + low dust SCR denitration device has a good operation effect and effectively extends the catalyst life [12]. In order to solve the problem of high-dust SCR denitration, a high proportion of coal-fired power stations in the United States use high temperature ESP. By 2006, the coal-fired power stations that installed with high temperature ESP accounted for 11.3% of the total installed capacity of the United States [13]. Therefore, high temperature dust removal before high temperature denitration is technically feasible.

High temperature ESP is usually adopted by coal-fired power stations in developed countries. Although high temperature ESP has been used for a long time, there are still some problems in practical application. The key problem is that the dust deposited on the plate is affected by high temperature, the loss of sodium ion is serious, the dust specific resistance increases rapidly in a short time, the

counter-corona phenomenon is prominent, the performance of ESP is significantly reduced, and the outlet dust concentration is unstable and abnormally high, usually fluctuating in the range of 30-100mg /Nm^3 or even higher [12].

In addition, the high temperature ESP and SCR denitration device abroad did not adopt the integrated design, are two independent equipment, so possessed the disadvantages of huge size, large floor space, high cost and etc.

Therefore, high temperature dust removal + high temperature denitration in cement industry can be carried out by using the integrated technology of dust collection and denitration of high temperature ultra-clean EFIP. As a mature technology that has been successfully applied, the high-temperature ultra-clean EFIP technology can cope with the flue gas conditions with high dust concentration and high dust specific resistance, and the outlet emission concentration can be less than 5mg/m^3, so there is no need to add the secondary dust removal process later. High temperature and low dust SCR is also a widely used mature technology, which can run efficiently by evenly arranging the flow field under dust-free conditions. High temperature ultra-clean EFIP technology and high temperature low dust SCR denitration technology are combined to form a high temperature dust collection and denitrification integrated technology, and its application in the cement field has the following advantages:

1 Stable outlet emission, with a minimum up to 5mg/Nm^3. Dust emission requirements can be met without secondary dust removal, reducing the total investment of the system

2 Outlet flue gas is dust-free flue gas, which can fully protect SCR catalyst, prolong service life and improve denitration efficiency.

3 The process equipment is reduced, saving the floor area and reducing the investment cost.

5 Conclusion

High temperature ultra-clean EFIP technology is a new generation of highly efficient dust removal technology based on conventional EFIP technology, using filtration

technology of alloy fiber filter media , the use of temperature can reach up to 400℃, can cooperate with SCR to achieve high temperature ultra-clean dust removal + low dust SCR denitration of new process of "dust first, denitration later" . The pilot test results in a power plant and the engineering application results in Shanxi Aluminum showed that the outlet dust concentration is stable, which can meet the requirements of ultra-low emission and improve the denitration effect of SCR and the service life of catalyst. This technology is a new dust removal method which is very suitable for cement industry. This technology can solve the problems of high dust concentration and denitrification difficulties in the cement industry, and can meet the ultra-low emission requirements of dust emission less than 5mg/Nm^3 and NOx emission less than 50 mg/Nm^3 without secondary dust removal. The SCR catalyst can be fully protected to extend its service life and significantly reduce the investment and operating cost.

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