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Review of Electrostatic Precipitator in China's Thermal Power Industry

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Abstract

The flue gas emission standards of thermal power plants in China have become more and mor stringent, which makes the dust removal technology upgraded continuously. This paper reviews the development history of dust removal technology in China's thermal power industry, introduces dry electrostatic precipitator and 3 new electrostatic dust removal technologies, and prospects the development direction of dust removal technology in China's thermal power industry. With excellent performance, electrostatic precipitators stood out and became the first choice for flue gas dust removal in coal-fired power plants. Dry electrostatic precipitator has high dust removal efficiency and low energy consumption, but its ability to treat fine particles needs to be improved. On the basis of dry electrostatic precipitators, many electrostatic precipitators have been derived, among which low-low temperature electrostatic precipitator, wet electrostatic precipitator and hybrid particulate collector have good application prospects. The electrostatic precipitator technology in China's thermal power industry is becoming more and more mature, and the development goals are low consumption, coordination, intelligence and standardization. This paper reviews the electrostatic precipitator in China's thermal power industry, which provides reference for readers who want to understand the development history and direction of this field.

Keywords

Thermal Power Industry; Dust Removal Technology; Electrostatic Precipitator.

1. Introduction

In the past 40 years of reform and opening up, China's power industry has developed rapidly: Generating capacity has increased by 30 times, of which thermal power capacity has increased by about 27 times, supporting an average annual growth rate of 9.5% in China 's economy [1]. Although people's demand for clean energy is gradually increasing, the characteristics of coal-rich, oil-poor and gas-poor energy reserves make it difficult for China to get rid of the development model with coal as the main energy source. Thermal power (especially coal-fired power) is still the main source of electricity in the coming period of time. Atmospheric pollutants from thermal power plants are mainly sulfur dioxide, nitrogen oxides and dust. Exhausting smoke with excessive dust concentration can lead to haze weather. With the stringent flue gas emission standards coming out, dust removal technology has been constantly updated. At present, electrostatic precipitation is widely used in China's thermal power industry, and its ability of controlling particulate emissions is excellent.

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2. Development History of Dust Removal Technology in China's Thermal Power Industry

Before the introduction of relevant national emission standards, China's thermal power plants mainly used cyclone dust collectors, multi-tube dust collectors, Venturi water film dust collectors and inclined rod grid dust collectors with low dust removal efficiency to control particulate emissions. In the early 1990s, electrostatic precipitator was rapidly popularized in coal-fired power plants and became the main dust removal equipment. Around 1996, the experiment of bag dust removal equipment was successful, and its dust removal efficiency could reach 99.7%. In 2011, after the introduction of the most stringent particulate emission standards for China's thermal power plants in history, the proportion of dry electrostatic precipitators decreased, while the sum of bag filter and electric bag composite precipitators was about 30%, and its dust removal efficiency was over 99.94 %.

The increasingly stringent emission standards have led to an endless stream of technological innovations in the field of flue gas dust removal in thermal power plants. The improved processes such as low-low temperature electrostatic precipitation technology, wet electrostatic precipitation technology and electric bag composite dust removal technology have greatly improved the dust removal efficiency compared with the traditional dry electrostatic precipitator. At the same time, it can also achieve the synergistic removal of multiple pollutants at low energy consumption.

3. Dry Electrostatic Precipitator

Dry electrostatic precipitator is a dust removal device that uses electrostatic force to separate dust from flue gas, which has 4 basic physical processes: ionization of gas, charge of flue gas dust, movement of charged dust to electrode and capture of charged dust. Dry electrostatic precipitator consists of inlet, outlet, dust collector, main body and high voltage power supply. Among them, the main body includes discharge electrode (corona electrode), dust collector (plate), insulation box and dust cleaning device. When high-voltage direct current is connected, an electric field sufficient to ionize the gas could be generated between the discharge electrode and the dust collector. Under the action of electric field, the charged dust will move to the electrode with opposite polarity and deposit on the electrode to achieve the purpose of trapping dust. After the automatic ash cleaning device vibrating the electrode, the dust attached to the electrode will fall to the bottom of the ash collecting hopper to achieve the enrichment of particulate matter. The appearance of dry electrostatic precipitator is shown in Fig. 1.

Fig 1. Appearance diagram of electrostatic precipitator

Dry electrostatic precipitator has the advantages of low energy consumption, high dust removal efficiency, wide application scope, low operation cost and high reliability, which is suitable for

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the occasions with high flue gas temperature and high pressure. The collection efficiency of the existing dry electrostatic precipitator for coarse particles in thermal power plants flue gas can reach 99.9%, but there is still room for improvement in the collection efficiency of fine particles. Because the fine particles in the range of 0.1 ~ 1.0 microns are difficult to charge, the electromigration rate is at a low valley, so the capture rate is low [2].

The author believes that the particle control ability of thermal power plants can be further enhanced by reforming the traditional dry electrostatic precipitator or developing multi-field coupling electrostatic precipitation technology. The route of reforming the traditional dry electrostatic precipitator is to increase the number of electric fields, the effective width and the effective height of the precipitator. Its core is to increase the dust collection area, thereby improving the removal efficiency of electrostatic precipitator, which covers a large area, has high investment and operation cost, and has narrow application scope. Limited by space, this paper only introduces 3 kinds of new electrostatic precipitator: low-low temperature electrostatic precipitator, wet electrostatic precipitator and hybrid particulate collector.

4. New Electrostatic Precipitator

4.1. Low-low Temperature Electrostatic Precipitator

Low-low temperature electrostatic precipitator is an equipment that arranges heat exchange device before the traditional dry electrostatic precipitator, which reduces the temperature of dust fume at the inlet of the device from 120 ~ 160 °C to the temperature below acid dew point (90-100 °C), so as to improve the performance of the precipitator. Low-low temperature electrostatic precipitation technology can be realized by adding low-temperature economizer or flue gas heat exchanger after the air preheater and before the electrostatic precipitator. The decrease of flue gas temperature can reduce the specific resistance of fly ash, the flue gas flow at the inlet of the dust collector and the wind speed of the electric field, thereby increasing the dust removal efficiency exponentially. In addition, it can also reduce the viscosity of gas, thereby increasing the electromigration rate of dust in flue gas, which is conducive to improving the collection of dust.

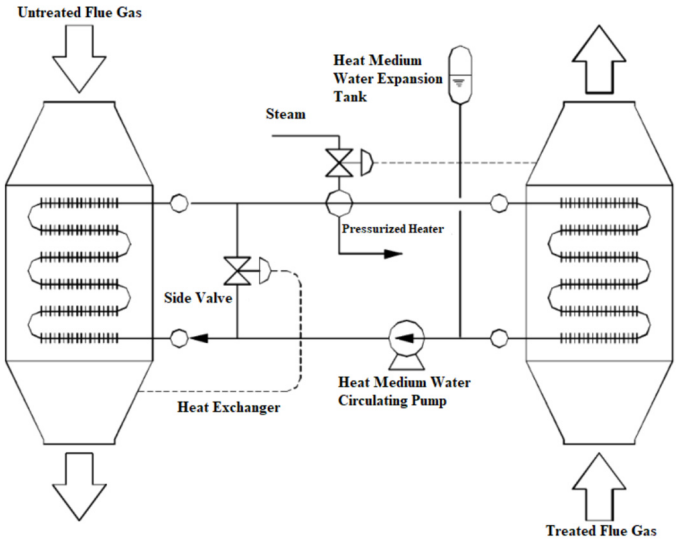

Fig 2. Extended gas-gas heater for lower temperature high efficiency flue gas treatment technology and its structure [5]

The flue gas heat exchanger adopts a two-stage heat exchanger system: the first stage is arranged at the inlet of the dust collector, and the flue gas temperature is cooled from 120 °C to

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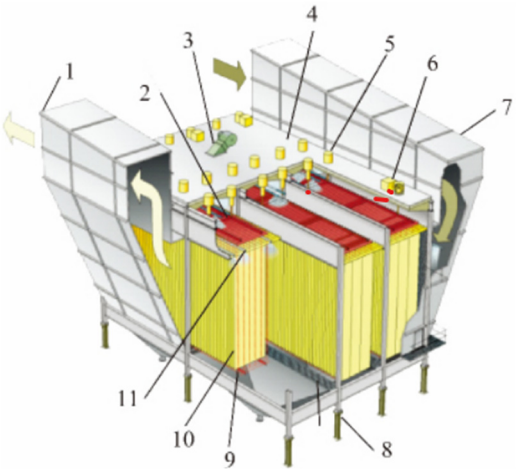
95 °C. The second stage is arranged in the horizontal flue in front of the chimney inlet, and the temperature of the flue gas rises from 47 °C to 72 °C after heating the flue gas after desulfurization [3,4]. The structure of low-low temperature electrostatic precipitator based on gas-gas heater is shown in Fig. 2.

Compared with the traditional dry electrostatic precipitator, the dust removal efficiency of the low-low temperature electrostatic precipitator is greatly improved. Besides, it can also improve the desulfurization efficiency of the downstream device, reduce the cooling water consumption of the wet desulfurization process and effectively alleviate the gypsum rain problem while realizing the utilization of heat. However, the decrease of flue gas temperature below the acid dew point may lead to the corrosion of low-temperature heat exchangers and electrostatic precipitators. Controlling the ratio of ash to sulfur (the ratio of dust concentration to sulfuric acid mist concentration) can prevent or weaken acid corrosion.

4.2. Wet Electrostatic Precipitator

The wet electrostatic precipitator is arranged behind the wet flue gas desulfurization system. Compared with the upstream dry electrostatic precipitator, the inlet flue gas dust concentration is relatively low. The difference between wet electrostatic precipitator and dry electrostatic precipitator is that the dry electrostatic precipitator adopts the vibration cleaning method, while the wet electrostatic precipitator sprays water to the dust collector plate and forms a continuous water film to flush the deposited particles away. The water film formed on the plate can greatly increase the discharge current in the electrostatic precipitator, enhance the charge capacity of fine particles, and further improve the removal efficiency.

Wet electrostatic precipitator is divided into horizontal and vertical forms. Vertical layout covers a small area and is suitable for ultra-clean emission renovation of existing power plants, while the investment of horizontal layout is small. The typical horizontal wet electrostatic precipitator structure is shown in Fig. 3.



(1-Flue Gas Outlet;2-Nozzle Cleaning;3-Purification Gas System;4-Top Operating Table; 5-Insulator;6-Transformer Rectifier;7-Flue Gas Entrance;8-Bracing Structure)

Fig 3. Horizontal wet electrostatic precipitator structure [6]

WESP overcomes the problems of anti-corona and secondary dust and has higher efficiency than traditional ESP. It contains droplets, which makes the flue gas humidity higher, so the corona voltage is lower and the discharge ability is stronger. In addition, WESP also has a strong ability to remove SO_3 acid mist, Hg and other pollutants. However, WESP may have a negative impact on the charge characteristics and mobility of particles, and its water spraying amount and liquid film thickness are difficult to control. Moreover, the mechanism of charge transfer in water film boundary layer is still unclear so that relevant theories still need further study.

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4.3. Hybrid Particulate Collector

Hybrid Particulate Collector is not a simple series of dry electrostatic precipitator and bag filter, but an organic combination of the former charged dust technology and the latter filter interception composite dust removal technology. The former stage electric field plays the role of pre-collection and charge while the latter stage filter bag plays the role of filtration and dust removal. The former electric field can remove more than 80% of the dust in the flue gas, and greatly reduce the dust concentration of the flue gas entering the latter filter bag area. The latter filter bag filters only 10 % ~ 20 % fine particles, which can effectively avoid the erosion and wear of coarse particles on the filter bag and improve the cake layer structure on the filter bag surface [7].

The hybrid particulate collector is divided into 3 types according to the combination forms: front electric type, electrostatic enhancement type and advanced hybrid type. Charged by electrostatic field, the particles will get filtration characteristics, which could lead them to be effectively captured by the filter bag, that is the working principle of electrostatic enhanced electrostatic bag composite dust collector. Advanced hybrid particulate collector (AHPC) has several dust removal units. Each dust removal unit contains electrostatic dust removal device and bag dust removal device. The electrostatic precipitator electrode and the filter bag are arranged alternately, as show in Fig. 4.

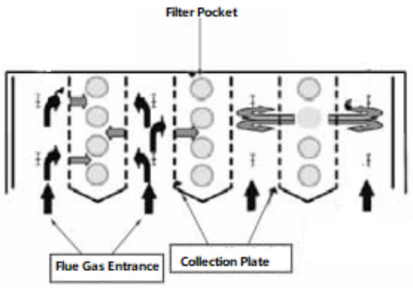

Fig 4. AHPC structure diagram [8]

Hybrid particulate collector has the advantages of low and stable outlet dust concentration, which is not easily affected by coal combustion components. Its filter bag has long service life, low operation and maintenance costs so that can operate efficiently and stably for a long time. However, the technology of hybrid particulate collector has not yet been fully mature. It cannot deal with high temperature flue gas easily (flue gas temperature is too high to allow the filter to be easily ' burned ' and damage the filter bag), and its requirements for flue gas humidity and oxygen content during boiler operation is high. In addition, the auxiliary system of it is complex and the operation failure rate is high.

5. Development Direction of Dust Removal Technology in China's Thermal Power Industry

The author believes that low consumption, coordination, intelligence and standardization are the 4 development directions of dust removal technology in China's thermal power industry. Low consumption means reducing the resources consumption, which need to be achieved by developing the solid waste recycling technology to recover and utilize the fly ash efficiently. Coordination refers to the synergistic removal of multiple pollutants in flue gas. By optimizing the process of pollutant control technology such as desulfurization, denitrification and dust removal, the integration of flue gas pollution control system can be realized, which could reduce the operating costs and increase system flexibility while ensuring the removal efficiency of various pollutants. Intelligence refers to the organic combination of pollutant control, big data

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technology and artificial intelligence. The pollutant control system of intelligent thermal power plant is established by using operation parameters, business data, market policy and other information, which could provide solutions for system design, equipment selection and operation failure elimination. Standardization means improving the standardized production level and modular assembly level of pollutant control equipment. On the one hand, shorten the construction period, reduce the impact on the host. On the other hand, enhance the international competitiveness of China's thermal power flue gas dust removal equipment.

6. Conclusion

Dust removal is an important pollutant control technology that is widely used in thermal power plants. There are many dust removal technologies that have been applied, electrostatic precipitators stood out because of their excellent performance. Dry electrostatic precipitator has high dust removal efficiency and low energy consumption, but its capture ability of fine particles needs to be improved. Based on the dry electrostatic precipitator, a large number of electrostatic precipitators are derived. Among them, low-low temperature electrostatic precipitator, wet electrostatic precipitator and hybrid particulate collector have good application prospects. There is much room for improvement in electrostatic precipitator of thermal power industry, which need to be developed and upgraded with the goal of low consumption, coordination, intelligence and standardization.

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