

# *Development Status and Trends of Petrochemical Waste Gas Treatment Technology*

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**Abstract:** With the rapid development of the global economy, the petrochemical industry has generated a large amount of exhaust gas while meeting energy needs. These exhaust gases are rich in harmful substances and pose a potential threat to the environment and human health. Therefore, the development of petrochemical waste gas treatment technology has become crucial. This article will explore the current status of petrochemical waste gas treatment technology and look forward to future development trends.

## **1. Introduction**

The petrochemical industry plays an extremely important role globally, but with the vigorous development of the industry, the issue of exhaust emissions has gradually become prominent. Therefore, the development and innovation of petrochemical waste gas treatment technology have become key issues that need to be urgently addressed.

## **2. Common waste gas treatment technologies**

### **2.1 Combustion method**

The combustion method is currently one of the most common petrochemical waste gas treatment technologies. It mixes exhaust gas with fuel and undergoes high-temperature combustion, converting harmful substances into harmless substances such as carbon dioxide and water. Although the combustion method is simple and effective, pollutants such as nitrogen oxides in the exhaust gas still have a certain impact on the atmospheric environment. The combustion method is a common petrochemical waste gas treatment technology that mixes and burns waste gas with air to convert harmful substances into harmless substances and release heat energy. The combustion method not only effectively treats waste gas, but also has the advantages of simple operation and low cost. The key to combustion based petrochemical waste gas treatment technology lies in adjusting the mixing ratio of waste gas and air and controlling the combustion temperature<sup>[1]</sup>. Excessive temperature can cause harmful substances in the exhaust gas to be unable to fully burn or generate more harmful substances, while excessively low temperature can cause the exhaust gas to not be completely burned and unable to meet emission standards. Therefore, the combustion process requires scientific design and adjustment based on different exhaust gas components and concentrations.

The combustion method petrochemical waste gas treatment technology is widely used in industries such as oil refining and chemical production. For example, in the refining process, the exhaust gas contains a certain proportion of harmful substances such as nitrogen oxide and hydrogen sulfide. By mixing exhaust gas with an appropriate proportion of air and burning at an appropriate temperature, nitrogen oxide can be converted into nitrogen and water, and hydrogen sulfide can be converted into sulfur dioxide and water<sup>[2]</sup>. This can achieve the goal of converting harmful substances in exhaust gas into harmless substances. The premise of combustion method petrochemical waste gas treatment technology is to ensure that the waste gas and air are fully mixed. A common method is to use a nozzle to spray and mix exhaust gas and air to increase the mixing effect. At the same time, it is also necessary to pre-treat the exhaust gas, such as dust removal and desulfurization, to reduce the corrosion and blockage of equipment caused by particulate matter and harmful substances.

The petrochemical industry has always been one of the important industries in China, but the accompanying problem is a large amount of exhaust emissions. These exhaust gases contain various harmful substances, posing a potential threat to the environment and human health. In order to address this issue, combustion method is widely used in petrochemical waste gas treatment technology. Combustion method is a method that utilizes high temperature and oxygen to completely oxidize organic substances in exhaust gas. Petrochemical waste gas treatment equipment usually includes pre-treatment systems, combustion furnaces, and exhaust gas treatment systems. The pre-treatment system is used to remove impurities such as particles and sulfides from the exhaust gas, ensuring that the exhaust gas enters the combustion furnace cleanly. The combustion furnace is a key link in the entire treatment process, and by controlling the appropriate combustion temperature and time, the organic substances in the exhaust gas are completely burned into carbon dioxide and water. Finally, the exhaust gas treatment system is used to remove nitrogen oxides and other harmful substances generated during the combustion process, ensuring that exhaust emissions comply with environmental standards.

The cost of combustion based petrochemical waste gas treatment technology is relatively low, making it suitable for large-scale waste gas treatment. However, the combustion process generates a large amount of heat energy. If this heat energy is not effectively utilized, it will not only cause energy waste, but also further pollute the environment. Therefore, in practical applications, it is necessary to combine it with energy recovery technology to effectively utilize the heat energy generated by exhaust gas combustion. Combustion method is a common petrochemical waste gas treatment technology that can convert harmful substances into harmless substances and release heat energy. It has the advantages of simple operation and low cost, and is widely used in industries such as oil refining and chemical production. However, it is necessary to scientifically design and adjust according to different exhaust gas components and concentrations during use, and combine it with energy recovery technology to maximize its effectiveness.

## 2.2 Adsorption method

Adsorption method is a technology that uses adsorbents to remove organic matter from waste gas. Commonly used adsorbents include activated carbon, molecular sieve, etc. The adsorption method has a significant effect in removing organic pollutants, but its removal efficiency for inorganic pollutants is relatively low. The adsorption method for petrochemical waste gas treatment technology is a commonly used waste gas treatment method, which achieves the purpose of purifying waste gas by adsorbing harmful substances in the waste gas onto specific adsorbents<sup>[3]</sup>. This technology is widely used in the petrochemical industry and can effectively remove pollutants such as organic compounds, sulfides, and nitrogen oxides from waste gas. The basic principle of adsorption method for petrochemical waste gas treatment technology is to use the physical or chemical forces between

the adsorbent and the pollutants in the waste gas, so that the pollutants are adsorbed on the surface or internal pores of the adsorbent, achieving the effect of purifying the waste gas. Common adsorbents include activated carbon, molecular sieve, silica gel, etc.

Activated carbon is a very commonly used adsorbent with strong adsorption capacity and high surface area, which can effectively adsorb organic substances in exhaust gas. The adsorption of activated carbon is achieved through physical adsorption, which is the interaction caused by van der Waals forces between pollutant molecules and the surface of activated carbon. Molecular sieve is an adsorbent with a specific pore structure that can selectively adsorb certain molecules in exhaust gas. Its adsorption is achieved through the interaction between molecules and molecular sieve pores, which can remove harmful substances such as sulfides and nitrogen oxides from exhaust gas. Silicone is a porous adsorbent with a large specific surface area and excellent adsorption performance. It can adsorb moisture, organic matter, and some gaseous pollutants in exhaust gas, and is commonly used in wet exhaust gas treatment systems. The adsorption method for treating petrochemical waste gas has the advantages of good treatment effect, simple operation, and low cost. However, the saturation of the adsorbent is a challenge for this technology, as its adsorption effect gradually decreases as the adsorbent saturates, requiring regular replacement or regeneration of the adsorbent.

Adsorption method is a commonly used petrochemical waste gas treatment technology that uses adsorbents to adsorb pollutants from the waste gas, thereby purifying the waste gas and meeting environmental requirements. The adsorption method for waste gas treatment technology is based on the adsorption between substances, using the active sites on the surface of the adsorbent to adsorb pollutants in the waste gas. Commonly used adsorbents include activated carbon, molecular sieve, alumina, etc. When the exhaust gas passes through the adsorption device, pollutants will be captured by the adsorbent and fixed on its surface, thereby achieving the purpose of purifying the exhaust gas. As the surface of the adsorbent saturates, it is necessary to regenerate or replace the adsorbent. The adsorption method for waste gas treatment technology is widely used in the petrochemical industry. For example, the waste gas generated during the refining process contains harmful substances such as hydrogen sulfide, benzene, and methanol, and the use of adsorbents can effectively remove these pollutants. In addition, adsorption method can also be used to treat waste gases such as formaldehyde, styrene, and chloroalkanes in petrochemical production. The adsorption method for treating petrochemical waste gas has several advantages. One is the wide selection range of adsorbents, which can be selected based on the characteristics of exhaust gas components and target pollutants, improving the treatment effect. The second is that the adsorption method has high treatment efficiency and removal rate, which can effectively purify waste gas. Thirdly, the adsorption method is easy to operate and has relatively small equipment, making it suitable for waste gas treatment in small and medium-sized enterprises

### **2.3 Desulfurization and denitrification technology**

Desulfurization and denitrification technologies are mainly used to control the emissions of sulfur oxides and nitrogen oxides in petrochemical waste gas. Common methods include wet desulfurization and selective catalytic reduction technology. These technologies can effectively reduce the emissions of harmful gases, but require higher cost inputs. Desulfurization and denitrification technology is a very important link in the treatment of petrochemical waste gas. During the production process of petrochemical industry, a large amount of exhaust gas is generated, which contains harmful substances such as sulfur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>). If discharged into the atmosphere without treatment, it will have serious impacts on the environment and human health<sup>[4]</sup>. Therefore, researching and applying desulfurization and denitrification technologies has become an effective method to solve this problem. Desulfurization technology mainly refers to the process of converting

sulfur dioxide in exhaust gas into forms such as sulfuric acid and sulfide, and absorbing, diluting or converting them. The most common desulfurization technologies are wet desulfurization and dry desulfurization. Wet desulfurization is achieved by contacting waste gas with alkaline solutions, causing sulfur dioxide to react with oxides in alkaline solutions to form sulfates, which are then absorbed by absorbers. Dry desulfurization is achieved by adding an adsorbent to adsorb sulfur dioxide in the exhaust gas onto the surface of the adsorbent.

### **3. Development of Emerging Waste Gas Treatment Technologies**

#### **3.1 Advanced oxidation technology**

Advanced oxidation technology is an emerging technology that utilizes strong oxidants to degrade organic waste gases. For example, ozone oxidation, hydrogen peroxide oxidation, etc. These technologies can effectively reduce the content of harmful substances in organic waste gas, but their equipment investment and operating costs are relatively high. Advanced Oxidation Process (AOP) is an emerging waste gas treatment technology widely used in the petrochemical industry. It can effectively degrade organic pollutants in exhaust gas and reduce environmental pollution. With the rapid development of the petrochemical industry, the issue of exhaust emissions is becoming increasingly prominent<sup>[5]</sup>. Traditional waste gas treatment methods often find it difficult to completely degrade organic pollutants, resulting in poor waste gas treatment efficiency. However, advanced oxidation technology can decompose organic pollutants into harmless substances by utilizing the high oxidation ability of strong oxidants such as hydrogen oxygen radicals, hydroxyl radicals, and superoxide radicals, thereby achieving the goal of waste gas purification. Advanced oxidation technology has multiple implementation methods, including photocatalytic oxidation, ozone oxidation, ultrasonic oxidation, etc. Among them, photocatalytic oxidation is a common advanced oxidation technology, which generates electron hole pairs through the absorption of ultraviolet light by photocatalysts, generating highly active species such as hydroxyl radicals, and then oxidizing organic pollutants. This technology has the advantages of high treatment efficiency, simple operation, and low energy consumption, and has been widely applied in the treatment of petrochemical waste gas.

Advanced oxidation technology has played an important role in the treatment of waste gases in the petrochemical industry. Firstly, this technology can efficiently degrade organic pollutants in exhaust gas and convert them into harmless substances, thereby reducing environmental pollution<sup>[6]</sup>. Secondly, advanced oxidation technology has wide applicability and can be used to treat different types of waste gases, including organic pollutants such as hydrocarbons, phenols, and alcohols. In addition, this technology can also treat secondary pollutants in exhaust gas, such as oxidation products of volatile organic compounds. Therefore, advanced oxidation technology is an economical and efficient waste gas treatment technology. Although advanced oxidation technology has shown good results in waste gas treatment in the petrochemical industry, it also faces some problems. For example, photocatalytic oxidation technology requires high selection and stability of catalysts, and it is necessary to find more effective photocatalysts to improve reaction efficiency. In addition, the equipment and operating costs of advanced oxidation technology are relatively high, and it is necessary to further reduce its application costs to promote its widespread application in the petrochemical industry.

#### **3.2 Biological treatment technology**

Biological treatment technology is a technology that utilizes microorganisms to degrade organic matter in waste gas. It has the advantages of environmental friendliness and low energy consumption, gradually becoming the development trend of petrochemical waste gas treatment. However, this

technology faces challenges when dealing with high concentration organic waste gases. Biological treatment technology is an emerging waste gas treatment technology, especially with broad application prospects in the petrochemical industry. Biological treatment technology utilizes microbial metabolic activity and biocatalysis to convert organic matter in waste gas into harmless substances. The most commonly used biological treatment technologies include biofilters, biofilm processes, and bio combustion. Biofiltration is a method of utilizing activated sludge beds and fillers to degrade organic matter and gases in waste gas. By adjusting the flow rate, temperature, humidity, and oxygen supply of the exhaust gas, the organic matter in the exhaust gas is degraded by microorganisms into carbon dioxide and water. The biological filter has the advantages of simple operation, low cost, and good treatment effect, and has a significant effect on the treatment of low concentration organic waste gas.

The biofilm method is a method that uses biofilms to convert organic matter in waste gas into harmless substances. A biofilm is a thin film formed by microorganisms adhering to the exhaust gas contactor. When the exhaust gas passes through the film, organic matter is degraded by microorganisms and converted into water, carbon dioxide, etc. The biofilm method has the advantages of high efficiency, easy maintenance, and not easily inhibited by toxins, making it suitable for the treatment of high concentration and complex components of waste gas. Biocombustion is a technology that utilizes microorganisms to oxidize organic matter in waste gas to generate heat energy. By regulating the oxygen supply in the exhaust gas, microorganisms can convert organic matter into CO<sub>2</sub>, H<sub>2</sub>O, and heat energy. Biocombustion technology has the characteristics of high efficiency and no need for external energy supply, which can effectively treat high concentration and high temperature waste gas.

### 3.3 New technologies for desulfurization and denitrification

The new technology of desulfurization and denitrification aims to efficiently reduce the use of oxidants and reduce treatment costs. For example, the combined application of catalytic oxidation and catalytic reduction technology can improve treatment efficiency and reduce energy consumption. Petrochemical industry is an important pillar of modern industry, but its exhaust emissions have always been one of the main sources of environmental pollution. Among them, sulfur oxides (SO<sub>x</sub>) and nitrogen oxides (NO<sub>x</sub>) are one of the main components of exhaust gas, posing a great threat to the environment and human health. In order to reduce the emissions of these harmful gases, new technologies for desulfurization and denitrification have emerged.

Desulfurization and denitrification technology refers to the process of removing sulfur and nitrogen oxides from waste gas through physical, chemical, or biological methods. The widely used desulfurization and denitrification technologies currently include wet method, dry method, and catalytic denitrification method. Wet desulfurization and denitrification technology is a method of desulfurization and denitrification that utilizes oxidants in aqueous solutions to react with sulfides and nitrogen oxides. This method has the advantages of good treatment effect and simple operation, but due to the need for a large amount of water resources and the generation of a large amount of wastewater, it causes certain pressure on the environment.

Dry desulfurization and denitrification technology utilizes solid adsorbents to adsorb sulfur and nitrogen oxides from waste gas, and remove them through physical or chemical methods. This method has the advantages of simple process and stable equipment, but the sulfur removal effect is relatively poor, and it will produce a large number of by-products, which will have a certain impact on the environment. Catalytic denitrification technology is a method of using catalysts to catalyze the reaction of nitrogen oxides in exhaust gas with reducing agents, converting them into nitrogen and water vapor for denitrification. This method has the advantages of high efficiency and good treatment



effect, but the stability and lifespan of the catalyst are the challenges it needs to solve.

With the continuous progress of technology, new technologies for desulfurization and denitrification are also emerging. For example, using biotechnology and microorganisms to degrade sulfur and nitrogen oxides in waste gas, and converting them into harmless substances through the action of microorganisms; Utilizing nanomaterials to catalyze sulfur and nitrogen oxides in exhaust gas, improving the efficiency of desulfurization and denitrification, and reducing energy consumption. The application of new technologies for desulfurization and denitrification can not only reduce environmental pollution in petrochemical enterprises, but also improve the quality of the working environment and protect the physical health of employees. At the same time, it also helps to slow down air pollution and greenhouse gas emissions, which has positive significance for environmental protection.

#### 4. Conclusion

The development of petrochemical waste gas treatment technology continues to advance, from traditional combustion methods to adsorption methods, desulfurization and denitrification technologies, and then to the rise of advanced oxidation and biological treatment technologies. In the future, we can look forward to the emergence of more environmentally friendly and efficient waste gas treatment technologies to achieve sustainable development and protect human health and the environment.

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