Characterization Study of Carbonaceous Pitch Fumes and Their Condensates

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Abstract

Anode plants in China predominantly utilize Regenerative Thermal Oxidizers (RTOs) to incinerate pitch fumes. The incineration process requires the addition of natural gas. To reduce natural gas consumption, it is proposed to utilize an in-plant baking furnace for the synergistic co-combustion of Volatile Organic Compounds (VOCs) and condensates from pitch storage tanks, ensuring that emissions meet regulatory standards. Transport and combustion experiments were conducted on condensates from existing fume pipelines to determine the conveying temperature to the baking furnace and the required combustion temperature. Additionally, VOC transport experiments during the melting of solid pitch were carried out to establish the VOC flow rate for the baking furnace injection. These studies provide a foundation for the development of multi-pollutant synergistic control technologies in carbonaceous fume treatment.

Keywords: Anode plants, Condensate transport, Condensate combustion, VOC combustion, Synergistic control.

1. Introduction

In 2024, China's anode block production capacity reached 30.366 million tonnes per annum (MTPA), with an output of 23.10 million tonnes, corresponding to a capacity utilization rate of 76.07 %. China accounts for two-thirds of the world's anode block production, ranking first globally. The Aluminum Corporation of China (CHINALCO) maintained its position as China's second-largest producer, with a total production capacity of 3.138 MTPA and an annual output of 2.857 million tonnes.

During the forming process of anode production, the melting of solid pitch and the storage of liquid pitch release substantial amounts of pitch fumes. Field measurements [1] show that the concentration of pitch fumes during pitch melting ranges approximately 1 300–1 600 mg/Nm^3, while that emitted from liquid pitch storage tanks is approximately 800–1 000 mg/Nm^3. The composition of these fumes is highly complex, containing more than one hundred hazardous substances such as carbazole, pyridine, naphthalene, phenanthrene, anthracene, and phenol. In particular, benzopyrene is recognized as a strong carcinogen.

Moreover, the *Emission Standard of Pollutants for the Aluminum Industry* stipulates special emission limits for pitch fumes: 30 mg/m^3 for emissions from cathode baking furnaces and pitch melting operations, and 20 mg/m^3 for emissions from anode baking furnaces and green anode production. Pitch fumes must be purified before discharge to ensure compliance with the standard.

Primary treatment methods for pitch fumes include electrostatic precipitation, adsorption, absorption, condensation, and incineration. (1) The electrostatic precipitation method exhibits very low removal efficiency for benzopyrene in pitch fumes. Moreover, it produces hazardous waste tar during the removal of pitch fumes, which to some extent contributes to secondary pollution. (2) Adsorption can be categorized into dry adsorption and resin adsorption. In dry adsorption, pitch fumes pass through layers of activated carbon or calcined coke, where organic compounds are captured. Although this approach delivers high adsorption efficiency, the adsorbents require frequent regeneration or replacement once saturated, resulting in considerable long-term operating costs.

The resin adsorption method employs specialized adsorption resins to capture organic constituents from pitch fumes. While the adsorption capacity is high and the resins can be regenerated and reused, the method is limited by the high cost of resins, low mechanical strength, and proneness to damage during operation. (3) The absorption method produces a large amount of wastewater during the removal of pitch fumes, leading to secondary pollution. Wastewater is difficult to treat and entails high treatment costs, and the process also causes severe corrosion to equipment. (4)

The condensation method lowers the temperature to condense gaseous organic compounds in pitch fumes into a liquid form, achieving both recovery and purification. It is effective for recovering high-boiling-point organic compounds but performs poorly with low-boiling-point compounds. However, this method requires high capital investment and operating costs. (5) The incineration method includes direct combustion and catalytic combustion. In direct combustion, pitch fumes are introduced into a combustion chamber, where organic compounds are burned at high temperatures (typically 700–800 °C), producing carbon dioxide and water. This method is highly efficient and suitable for treating high-concentration pitch fumes, but it needs high energy consumption and operating costs.

Catalytic combustion, on the other hand, burns pitch fumes at lower temperatures (typically 200–400 °C) in the presence of catalysts, such as noble metals or metal oxides. The advantages of this method include a lower ignition temperature and reduced energy consumption, but it comes with the disadvantages of high catalyst costs and the risk of catalyst intoxication and deactivation.

Compared to methods such as electrostatic precipitation, adsorption, absorption, and condensation, incineration is the method that offers the most thorough treatment of pitch fumes. However, it requires additional fuel and results in high energy consumption. According to the *Guidelines on Strengthening the Response to Heavy Pollution Weather and Consolidating Emergency Emission Reduction Measures*, carbon manufacturers shall be categorized as Class A, and are required to adopt incineration processes to treat organic exhaust gases, including pitch fumes. Therefore, under the premise of minimizing energy consumption, incineration is the most effective method for pitch fumes control in China’s carbon industry.

Carbon manufacturers typically use pot baking furnaces, where the flue temperature can reach up to 1350 °C. Based on this, the project team proposed [2, 3] utilizing the high-temperature flues of these pot furnaces to directly incinerate pitch fumes, in order to reduce energy consumption. This approach eliminates the need for additional energy input, as the pitch fumes can serve as fuel for the furnace. The heat generated during combustion can be recovered and reused, thereby achieving emission reduction and carbon mitigation, and simultaneously lowering production costs.

After being heated at a constant temperature of 180 °C in a forced-air drying oven for approximately 89 hours, the solid pitch exhibited a volatilization rate of 3.66 %, indicating that the generated pitch fumes accounted for 3.66 % of the mass of the solid pitch.

According to reference [5], pitch fumes do not condense at temperatures above 400 °C. Given the practical difficulty of maintaining accompanying temperatures above 400 °C, condensation of pitch fumes in the transfer line is deemed acceptable. The critical requirement is that the condensate must be able to flow out of the pitch fumes pipeline, which can be ensured by maintaining the temperature inside pipeline above 90 °C. In this study, the uncondensed gas in the pitch fumes is referred to as VOCs, while the condensed material is termed condensate. The mass ratio of VOCs to condensate is 1:4 [6]. This provides a theoretical basis for selecting the induced draft fan for VOCs transport and determining the appropriate size for the condensate storage tank in the experimental setup.

2.2.4 Combustion Experiment of VOCs

VOCs refer to the substances remaining after the condensation of pitch fumes. Due to their similar combustion characteristics to pitch fumes and their feature to combust at temperatures above 800 °C, further experimental investigation was deemed unnecessary.

3. Conclusions

This study addresses the high energy consumption associated with incineration of pitch fumes in anode plants. Through an investigation of the characteristics of carbonaceous pitch fumes and their condensate, the following key conclusions were drawn:

1) For the synergistic treatment of pitch fumes, condensation is permitted, with separate processing of VOCs and condensate.

2) During transport, the condensate temperature should be maintained above 90 °C.

3) The combustion temperature of the condensate should be above 580 °C.

4) The yield of pitch fumes should be determined through volatilization experiments of the pitch.

4. References

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