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Short Communication

A Novel Process of Pressurized Condensation-Coupled Absorption for Dichloromethane Removal from Exhaust Gas in Supramolecular Polyethylene Production

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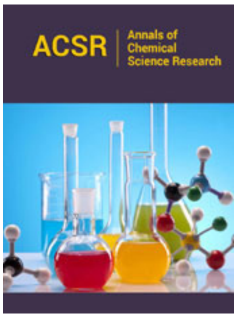

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Abstract

This study introduces a cutting-edge process aimed at effectively removing dichloromethane from exhaust gas during supramolecular polyethylene production. The proposed technique utilizes pressurized condensation-coupled absorption, providing improved efficiency and environmental sustainability. Among them, 97.4% of the dichloromethane can be separated through condensation and the remaining portion that cannot be condensed is removed through absorption using white oil. By optimizing the parameters and implementing advanced absorption technology, this new process offers a promising solution for mitigating the harmful effects associated with dichloromethane emissions.

Introduction

Ultra-high molecular weight polyethylene (UHMWPE) generally refers to linear long-chain polyethylene materials with an average molecular weight of over one million. It is currently the highest in terms of specific strength and specific modulus among all fibers. UHMWPE exhibits exceptional properties such as high strength, impact resistance, wear resistance, self-lubrication, chemical corrosion resistance and low-temperature resistance. Its main products include fibers, films, pipes, sheets, rods, porous materials and profiles, widely used in aerospace, defence industry, marine engineering, rail transportation, municipal construction, petrochemicals, mining, metallurgy, power and new energy materials fields. UHMWPE fibers, carbon fibers and aramid fibers are collectively known as the three major high-performance fibers in the world and are irreplaceable new materials.

Currently, the wet spinning process is commonly employed for the production of UHMWPE fibers. This involves mixing UHMWPE powder with additives, adding them into mineral oil, thoroughly mixing to form a spinning solution. The solution is then extruded through spinnerets, cooled to obtain gel filaments, followed by extraction with dichloroethane, drying and stretching to produce UHMWPE fibers.

During the process, it is necessary to extract and dry the spinning solvent, mineral oil, in the later stage of spinning. Dichloromethane is commonly used as an extraction agent. After removing the mineral oil through dichloromethane extraction, the gel filaments still contain residual dichloromethane, which is released as exhaust gas during subsequent drying. Purifying the exhaust gas to meet emission standards poses a technical challenge for the industry [1].

Currently, the method used to treat dichloromethane-containing exhaust gas generated during production is adsorption. However, due to the high concentration of dichloromethane in the exhaust gas, the activated carbon adsorbents in the adsorption tower easily reach saturation. The activated carbon adsorption and recovery method is most suitable for treating organic waste gas with VOC concentrations ranging from 500 to 10,000mg/Nm^3. The concentration of dichloromethane in the exhaust gas during the production process far exceeds this value and reaches 0.35kg/Nm^3, making it difficult to achieve emissions compliance. Increasing dichloromethane consumption costs, resulting in reduced economic benefits. Additionally, the regeneration of saturated adsorbents consumes a high amount of energy and there are issues of secondary pollution during the treatment of spent adsorbents.

The purpose of paper is to address the deficiencies in the existing background technology and provide a process of pressurized condensation-coupled absorption for removing dichloromethane from exhaust gas. This process overcomes the challenges of achieving emissions compliance with activated carbon adsorption and the high energy consumption of adsorption regeneration systems.

Methods and Materials

In this study, we propose a novel approach based on pressurized condensation-coupled absorption. This method involves that the dichloromethane exhaust gas generated from the drying process in the production of ultra-high molecular weight polyethylene is compressed using a compressor to a pressure of 8-10 atmospheres. The compressed dichloromethane exhaust gas is then cooled to 0-20 °C in a condenser, causing a portion of the dichloromethane in the gas to condense and separate as a liquid. The condensed dichloromethane gas, along with entrained impurities, exits the condenser and enters the bottom of an absorption tower. At the bottom of the absorption tower, the entrained impurities and condensed dichloromethane gas come into counter-current contact with the absorbent white oil sprayed from the top of the tower. The dichloromethane dissolved in the white oil is thus removed from the gas. The exhaust gas exiting the top of the absorption tower meets emission standards regarding dichloromethane content. The white oil, after regeneration is recycled for reuse following dichloromethane absorption from the gas.

Results and Discussion

According to Dalton's Law: The vapor pressure of each gas component in a mixed gas is equal to the percentage of volume occupied by that gas. For the mixture of dichloromethane and air: At 20 °C, the saturated vapor pressure of dichloromethane is 47.39kPa, indicating that dichloromethane accounts for approximately 46.8% of the mixture. Considering minimal pressure changes before and after the condenser, lowering the temperature of the mixture to 0 °C, the saturated vapor pressure of dichloromethane at 0 °C is 19.2kPa, with dichloromethane comprising about 18.9% of the mixture. When the mixture of dichloromethane and air is cooled from 20 °C to 0 °C using atmospheric pressure without compression, only around 74% of the dichloromethane condenses and becomes a liquid solvent.

If the pressure of the dichloromethane mixture at 0 °C is increased from one atmosphere to nine atmospheres (gauge pressure of 800kPa), and then the mixture is cooled to 0 °C, based on the partial pressure principle, the concentration of dichloromethane is 18.9%. Therefore, the partial pressure of dichloromethane is calculated as 170.3kPa. However, according to the partial pressure principle, the saturation vapor pressure at 0 °C is solely dependent on temperature and is 19.2kPa. Since 170.3kPa greatly exceeds this value, the excess dichloromethane will turn into a liquid state, maintaining the partial pressure of dichloromethane at is equal to 19.2kPa. Calculation shows that at this point, the concentration of dichloromethane in the gas is 2.1%. Based on these calculations, when the mixture of dichloromethane and air at 20 °C is compressed to 800kPa (gauge pressure) and subsequently cooled to 0 °C, only 2.1% of the non-condensed gas contains dichloromethane, while approximately 97.6% of dichloromethane condenses and is reused as an extractant.

After compressing and condensing, the gas can be further absorbed using white oil, making it easier to meet emission standards regarding dichloromethane content in the exhaust gas. The absorption solution containing dichloromethane and white oil can enter a distillation and regeneration system, where dichloromethane and absorbent white oil can be obtained separately from the top and bottom of the distillation column, respectively, for recycling within the system.

Conclusion

In conclusion, this study presents a novel process for removing dichloromethane from exhaust gas in supramolecular polyethylene production. The pressurized condensation coupled absorption technique offers an efficient, environmentally friendly and sustainable solution for mitigating dichloromethane emissions. Further research is warranted to optimize process parameters, evaluate long-term performance and assess potential scale-up opportunities. Implementation of this innovative process holds great promise for reducing the environmental impact of supramolecular polyethylene production.

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Declarations

Conflict of interest: The authors declared that they have no conflicts of interest to this work.

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