Technology of CO$_2$ capture and storage

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**Abstract** This paper studies carbon capture and storage based on carbon emission. There are three main technical routes for CO$_2$ emission reduction: pre-combustion capture, oxygen-rich combustion, and post-combustion capture. CO$_2$ separation technology mainly includes: chemical absorption method, solid adsorption method, membrane separation method. CO$_2$ capture needs to be transported to a special place for storage, which can be generally divided into geological storage, marine storage and chemical storage. Future carbon capture research will focus on cost savings and energy savings.

1. Introduction

The impact of greenhouse gases on global climate is becoming increasingly apparent. The burning of fossil fuels has become the most important source of CO$_2$ emission, and the continuous increase of CO$_2$ concentration in the atmosphere will lead to climate change and global warming. Therefore, it is urgent to reduce CO$_2$ emission as much as possible. Power plants are currently the largest source of industrial carbon, so controlling CO$_2$ emissions from power plants can effectively reduce the concentration of CO$_2$ in the atmosphere. CO$_2$ capture and storage (CCS) is an important way to reduce CO$_2$ emissions, the technology of CO$_2$ capture and storage (CCS) refers to the separation of CO$_2$ from industrial or energy-related emission sources, transportation to certain locations for storage, and long-term isolation from the atmosphere [1]. The current CO$_2$ technology has some limitations: Emission reduction measures have energy consumption in the process of equipment manufacturing, installation and operation, and the utilization efficiency of new energy, such as wind energy, solar energy, biomass energy and low-carbon energy, is still low [2]. Therefore, it is very important to adopt reasonable CO$_2$ emission reduction methods. The CO$_2$ capture and separation play an important role in the CO$_2$ emission reduction process.

2. CO$_2$ capture technology

Currently, CO$_2$ capture can be divided into three technical routes (1) post-combustion capture (2) pre-combustion capture (3) oxygen-rich combustion [3].

2.1 Post-combustion capture

Post-combustion capture technology is a technology to capture CO$_2$ from the flue gas generated after the fuel is burned in the air. The CO$_2$ generated parts in the power plant are mainly boilers and internal combustion engines, which have large equipment and are difficult to be reformed. Therefore, only the flue gas captured after combustion can be used to reduce CO$_2$ emissions. There are many power plants in China, so the application of post-combustion capture is very wide. However, the disadvantages of this technology lie in the large volume of flue gas, low emission pressure and low partial pressure of CO$_2$ in the power plant, resulting in high investment and operation cost [4].

2.2 Pre-combustion capture

First, fossil fuels are gasified into gas under certain pressure and temperature conditions in a steam environment. CO in the gas is converted into H$_2$ and CO$_2$ in the water-gas conversion reactor, which transfers the fuel chemical energy into H$_2$. Then CO$_2$ and H$_2$ are separated through separation technology, and the H$_2$ separated can be used as fuel for power plant or for fuel cell development [5]. The CO$_2$ mixture produced by this pre-combustion capture method is relatively high in concentration and easy to be sequestered. The gasification of solid fuel and the storage of H$_2$ as a by-product are the main technical bottlenecks of this technology.

2.3 Oxygen-enriched combustion

Oxygen-rich combustion USES extremely pure oxygen to replace the traditional air and fossil fuels, and takes part in combustion reaction in combustion chamber together with some high-concentration CO$_2$ returned after combustion to generate flue gas dominated by H2O and CO2 [6]. The water is then condensed into a liquid by physical cooling to separate the pure CO$_2$. The advantage of oxygen-rich combustion is that the products are almost only H2O and CO2, so CO2 can be captured

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effectively. Meanwhile, due to the reduction of nitrogen content, the NOX content generated is also reduced, thus reducing the cost of NOX removal. The difficulty of this scheme lies in the high cost of obtaining pure oxygen conditions.

3. CO2 separation technique

The separation technologies used for CO2 capture mainly include chemical absorption, solid adsorption, and membrane separation.

3.1 Chemical absorption method

The main method used for large-scale CO2 capture in industry is alcohol amine method, among which the commonly used absorbents are ammonia, ethanolamine (MEA), diethanolamine (DEA), methylethanolamine (MDEA) and triethanolamine (TEA0), etc. These substances capture CO2 mainly by the interaction of amino groups in amines with CO2. The chemical absorption process is shown in Fig. 1. After that , the liquid intermediate compound passes through the heat exchanger to exchange heat with the dilute solution coming out of the regenerator. It is then heated in the regenerator and then decomposed into absorbent and CO2. Finally, the adsorbent generated is transported to the liquid storage tank to form a complete cycle. The pressure difference required by the solvent returning to the absorption chamber is provided by the booster pump. The captured CO2 is condensed, dehydrated, compressed and transported to storage sites for storage.

From the perspective of engineering application, solid adsorption eliminates the flow of liquid waste. In addition, solid adsorbents do not volatilize, which can avoid a large amount of energy loss related to the regeneration of absorbent.

3.3 Membrane separation method

Membrane separation refers to the selective separation of CO2 from gas through membrane under certain conditions. According to the different membrane materials, there are mainly polymeric membrane, inorganic membrane, mixed membrane and other filtration membrane under development. Membrane separation technology has the advantages of low investment, low energy consumption, small footprint and convenient maintenance, etc., which has attracted much attention in the field of CO2 capture. The transfer of CO2 in the membrane depends on solution-diffusion, and the transfer process consists of three steps: ①CO2 adsorbed and dissolved on the upper surface of the membrane;②CO2 diffuses through the membrane under the action of partial pressure difference on both sides;③CO2 desorption on the downstream surface of the membrane. The permeability rate mainly depends on the solubility and diffusion coefficient of CO2 in the membrane. At present, CO2 membrane separation
technology has been developed to some extent, but the poor separation performance of the membrane restricts the development of this technology.

4. CO2 sequestration

After CO2 capture, the high-purity CO2 needs to be further treated. Transport CO2 to a storage site for storage. Due to large CO2 emissions, permanent storage is generally required, so it is also called storage. CO2 sequestration requires the selection of suitable CO2 sequestration sites and monitoring, verification and risk assessment. In addition, environmental impact, low cost and national and international law norms are also considered [11]. The main ways of CO2 storage are geological storage, Marine storage and chemical storage.

Geological storage: geological storage refers to the use of natural gas similar to the geological storage principle of CO2 storage. CO2 Geological storage technologies can be broadly classified into the following categories: Depleted reservoir storage; Oil and gas reservoir storage (CO2 is stored in the mined oil and gas field with enhanced oil recovery technology and high-pressure gas recovery technology); Storage of unrecoverable coal seams (using enhanced methane recovery technology in coalfields); Deep saline layer sequestration; Other rock formations are sequestration, such as basalt and oil shale [12].

Ocean storage: The carbon sequestration capacity of the oceans far exceeds that of the terrestrial biosphere and atmosphere. Ocean sequestration refers to the capture of CO2 that is liquefied treatment, sent to the designated sea area, using pipeline technology into a certain depth of the ocean for storage. Marchetti [13] first proposed the idea of CO2 ocean storage in 1977. He proposed to inject CO2 collected by different ways into the deep sea area in the form of gas, liquid and solid respectively, and make it automatically form very stable solid hydrate under specific high pressure and low temperature conditions in the deep sea, so as to realize long-term sequestration and isolation of CO2.

Chemical storage: metal oxide reacts with CO2 through chemical reaction to form inorganic carbonate, which is then permanently sealed. It is currently in the research stage, but its small-scale application has been successful. It reacts to form inorganic carbonate, which is then sequestered permanently. However, the application of this technology requires large amounts of energy, minerals and proper disposal of waste.

5. Conclusion

Aiming at the demand of energy conservation and emission reduction, this paper conducted research on CO2 capture and storage. The three technical routes of CCS technology are: (1) post-combustion capture (2) pre-combustion capture (3) oxygen-rich combustion. The separation methods of CO2 mainly include chemical absorption, solid adsorption and membrane separation. Then the captured CO2 needs to be sequestered, in which CO2 is sequestered mainly through three methods: geological sequestration, Marine sequestration and chemical sequestration.

China's development status determines that it will also use fossil fuels on a long-term and large-scale scale. At the present stage, CO2 capture and storage has made a considerable contribution to China's CO2 emission reduction. At present, the cost and energy consumption of CCS technology are still very high, so the key to the future development of CO2 capture and storage technology is to reduce energy consumption and cost.

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