Technology of CO₂ 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 CO₂ emission reduction: pre-combustion capture, oxygen-rich combustion, and post-combustion capture; CO₂ separation technology mainly includes: chemical absorption method, solid adsorption method, membrane separation method. CO₂ 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 CO₂ emission, and the continuous increase of CO₂ concentration in the atmosphere will lead to climate change and global warming. Therefore, it is urgent to reduce CO₂ emission as much as possible. Power plants are currently the largest source of industrial carbon, so controlling CO₂ emissions from power plants can effectively reduce the concentration of CO₂ in the atmosphere. CO₂ capture and storage (CCS) is an important way to reduce CO₂ emissions, the technology of CO₂ capture and storage (CCS) refers to the separation of CO₂ from industrial or energy-related emission sources, transportation to certain locations for storage, and long-term isolation from the atmosphere [1]. The current CO₂ 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 CO₂ emission reduction methods. The CO₂ capture and separation play an important role in the CO₂ emission reduction process.

2.CO₂ capture technology

Currently, CO₂ 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 CO₂ from the flue gas generated after the fuel is

burned in the air. The CO₂ 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 CO₂ 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 CO₂ in the power plant, resulting in high investment and operation cost [4].

2.2 Precombustion 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 H₂ and CO₂ in the water-gas conversion reactor, which transfers the fuel chemical energy into H₂. Then CO₂ and H₂ are separated through separation technology, and the H₂ separated can be used as fuel for power plant or for fuel cell development [5]. The CO₂ 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 H₂ 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 CO₂ 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 CO₂. The advantage of oxygen-rich combustion is that the products are almost only H₂O and CO₂, so CO₂ can be captured

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. [7]. These substances capture CO₂ mainly by the interaction of amino groups in amines with CO₂. The chemical absorption process is shown in Fig. 1.[8], After the flue gas enters the absorber, CO₂ in the flue gas reacts with the absorber to form intermediate compounds. 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 [8]. The captured CO₂ is condensed, dehydrated, compressed and transported to storage sites for storage. The advantage of this method is that it can produce relatively pure CO₂ airflow, but the disadvantage is that the equipment cost is high and the energy consumption is large.

Fig. 1. Chemical absorption process flow

3.2 Solid adsorption method

Solid adsorption method refers to the selective adsorption of CO₂ with adsorbent under certain conditions (temperature, pressure, etc.), and the desorption of CO₂ by changing the conditions so as to achieve the purpose of separating CO₂. Solid adsorbent materials mainly activated carbon, molecular sieve, zeolite, MOF materials, etc. According to the adsorption conditions, the adsorption method can be divided into variable temperature adsorption (TSA) and pressure

swing adsorption (PSA). The adsorption method mainly relies on van der Waals force to adsorb CO₂ on the surface of the adsorbent, and its adsorption capacity mainly depends on the structural characteristics of the adsorbent and the pressure and temperature conditions in the process. In the case of variable temperature adsorption, the control speed of temperature regulation is slow, the efficiency is low, and a large amount of adsorbent is needed, which leads to the high cost of this technology. Therefore, pressure swing adsorption method is generally adopted in the industry, while variable temperature adsorption method is rarely used [9].

Solid adsorption technology can be divided into: (1) fixed bed technology. Fixed bed adsorption usually involves the use of packed beds containing granulated sorbent or structural sorbent. These packed beds can be configured as single containers or used to simulate moving beds or rotating arrangements [10]. (2) Mobile bed technology. Mobile adsorption system refers to any system involving the transport of granulated adsorbent between different containers used for adsorption; Examples are mobile beds and fluidized beds. Mobile bed adsorption means that the fluid to be treated flows from top to bottom in the tower. When it comes into contact with the adsorbent, the adsorbent is adsorbed. The saturated adsorbent is discharged continuously or intermittently from the bottom of the tower, and fresh or regenerated adsorbent is added to the top of the tower. Fluidized bed adsorption operation is an adsorption operation in which the fluid flows from bottom to top and the velocity of the fluid is controlled within a certain range to ensure that adsorbent particles are held up but not taken out and carried out in a fluidized state [11].

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 [4]. 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: ① CO₂ adsorbed and dissolved on the upper surface of the membrane; ② CO₂ diffuses through the membrane under the action of partial pressure difference on both sides. ③ CO₂ 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: ① Depleted reservoir storage; ② 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); ③ Storage of unrecoverable coal seams (using enhanced methane recovery technology in coalfields); ④ Deep saline layer sequestration; ⑤ 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 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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