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Path analysis on CO_2 resource utilization based on carbon capture using ammonia method in coal-fired power Plants

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ABSTRACT

With the deepening of carbon capture research using ammonia solution, CO_2 disposal problem after carbon capture has become an important limiting factor affecting the industrial applications of carbon capture technology. It can be seen that CO_2 not only controls as a greenhouse gas, but also it is a valuable carbon resource at the same time, CO_2 resource recycling has a very good market prospects in near future. Two viable paths for CO_2 resource utilization based on carbon capture using ammonia solution are divided in the paper. One path is regenerative resource utilization, i.e., rich liquid regenerates after the decarbonization reaction; the desorbed CO_2 is sequestrated under geological layer or reused in other fields. Another path is transformed resource utilization; flue gas decarbonization combines with chemical production, and the ingredients produced from the reaction of ammonia with CO_2 are transformed, carbon is fixed into nitrogen fertilizer or other chemical products, such as soda. The existing problems and the economic performance of CO_2 resource utilization in power plants were reviewed in the paper. CO_2 resource utilization based on carbon capture using ammonia solution is beneficial to the carbon emission reduction in coal-fired power plants; especially transformed resource utilization has economic advantage and good application prospects.

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1. Introduction

Shaun et al. from U.S. published a research report in Science, said that over the past decade, the average global temperature was higher than that of more than 80% particular years in the past 11,300 years. Over the last 100 years or so, the temperature increased significantly, which was consistent with the increasing trend of atmospheric CO_2 concentration after industrial revolution, the fact proved that global warming was a result of human activities [1]. According to data released by the Economic Cooperation and Development (OECD) and the International Energy Agency (IEA), about 10.6 billion tons CO_2 was discharged from the existing power plants, accounting for 40.6% of the total CO_2 emissions worldwide, among these coal-fired power plants CO_2 of 7.6 billion tons was emitted, accounting for 72% of the total emissions in the power generation industry [2]. For example, coal accounted for more than 65% of the primary energy production and consumption in China, CO_2 emissions from thermal power plants kept at about 60% of the total emissions [3,4]. Therefore, Carbon Capture Utilization and Sequestration (CCUS) for the power plants is more feasible measure to slow down CO_2 emission in the near future [5].

Flue gas post-combustion CO_2 capture in coal-fired power plants consists of absorption, adsorption, membrane separation, chilling ammonia, etc. Considered with CO_2 in flue gas with low partial pressure, huge gas flow rate as well as complex co-existing components in flue gas, the chemical absorption method is a more appropriate choice compared with other methods [6]. In the chemical absorption method, the most serious concern is alcohol amine method, in which monoethanolamine (MEA) is used most extensively, but its CO_2 absorption efficiency is not high, the regeneration product is only CO_2, and due to oxidation, thermal degradation, irreversible reactions and heat evaporation causes the loss of absorbing capacity, degradation products from rich CO_2 absorption solution (referred to as the rich liquid) cause system corrosion, furthermore, energy consumption in generation process, the initial investment and the operation cost are all high [7]. In order to solve these problems, in recent years, researchers have proposed carbon capture using ammonia solution to replace the traditional MEA absorption [7,8]. Then, the technical and economic feasibilities on CO_2 removal using ammonia solution have been explored by many researchers and research institutions, the results indicate that minimizing the decrease of power plant production efficiency can be achieved through the multi-pollutants control in power plants using ammonia solution [9].

With the in-depth research, researchers realized that CO_2 was a valuable carbon resource, the possibility of its resource recycling should be considered simultaneously, therefore carbon capture using ammonia method should think over not only the reduction of CO_2 emission, but also the dispose of CO_2 after decarbonization [10]. Two feasible resource path based on CO_2 capture using ammonia solution (ammonia decarbonization) were divided in the paper, as shown in Fig. 1. One path is regenerative resource utilization: the rich liquid is regenerated after decarbonization, regeneration method consists of conventional heating regeneration and regeneration through ion exchange resin [8,11–16], then the desorbed CO_2 is sequestrated or used in other fields; another path is transformed resource utilization which combines the flue gas decarbonization with chemical production, the products after the CO_2 capture using ammonia solutions transform and fix into nitrogen fertilizer or other chemicals [17–20].

In view of the results of previous studies, a review about the paths of CO_2 resource utilization based on CO_2 capture using ammonia solution was carried out, related mechanisms, application prospect and economic aspect were investigated, existing problems and further development direction were also given, and the research could provide valuable contribution to the future development of carbon emission reduction.

2. The paths of CO_2 resource utilization

2.1. CO_2 capture using ammonia solution

2.1.1. Mechanism and progress of CO_2 capture using ammonia solution

CO_2 capture using ammonia solution could be traced back to 1997, Bai et al. [8] used ammonia solution to capture CO_2 from flue gas in power plants, and the studies on factors affecting CO_2 removal efficiency and absorption capacity were carried out in a semi-continuous bubbling absorption device [21]. Since then, the bubbling reactor, stirred tank, packed tower, sieve column, overweight bed and other equipment were applied for studying the CO_2 capture using ammonia solution, many relevant lab data were obtained [15,22–29]; in addition, Aspen Plus software was used to simulate and evaluate the technical and economic feasibility of flue gas CO_2 capture using ammonia solution in power plants [17,30,31], the results could improve the design of the carbon capture process. With further researches, CO_2 capture using ammonia solution attracted more and more attention, experimental study of ammonia carbon capture was carried out, and the results of infrared spectroscopy showed that the main content of solution was NH_4HCO_3 [24,32]. According to recent researches, for the solubility limit of NH_4HCO_3, the regeneration ammonia decarbonization technology without crystal in low concentration condition should apply ammonia solution with concentration less than 2 mol/L, and with the mass fraction of 2%, removal efficiency of CO_2 could be more than 90% [33,34]. But the high concentration ammonia solution can lead to ammonia escape and crystallization causing clog, which must be solved towards the industrial application while the crystal is the base of regenerative resource utilization and transformed resource utilization [35,36].

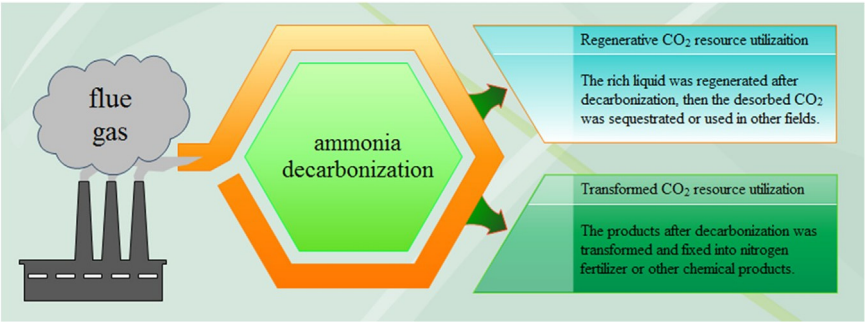

Fig. 1. Two feasible resource paths based CO_2 capture using ammonia solution in power plants.