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Review

Progress in reducing calcination reaction temperature of Calcium-Looping CO_2 capture technology: A critical review

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ABSTRACT

The calcium looping (CaL) process is a promising CO_2 capture technology based on a reversible reaction, CaO(s) + CO_2(g) ↔ $CaCO_3$(s), and the forward and reverse directions of this reaction are often referred to as carbonation and calcination. Although CaO-based sorbent has the advantages of abundant reserves, low cost, and high theoretical capacity of CO_2, it is limited by significant sintering of CaO grains over carbonation/calcination cycles, resulting in a rapid decline in CO_2 capture performance. As an essential part of CaL technology, the $CaCO_3$ calcination stage has a decisive influence on the sintering degree of CaO grains. In this work, a systematic understanding of fundamental aspects of the $CaCO_3$ calcination is reviewed. The effects of calcination reaction conditions on the sintering of CaO grains and the resulting decline in CO_2 capture performance during the cyclic operation were discussed. A number of efforts to reduce the calcination reaction temperature, thus slowing down CaO grains sintering, have been summarized, such as decreasing $CaCO_3$ crystallinity, doping $CaCO_3$ with alkali/alkaline earth salt, reducing CO_2 absolute pressure, injecting steam, as well as in situ converting CO_2. Finally, the future development trends for the above strategies to reduce the $CaCO_3$ calcination temperature are also recommended. We hope this work can help and inspire researchers to make breakthroughs in this field.

1. Introduction

It is well known that carbon dioxide (CO_2) is the primary greenhouse gas responsible for climate change, such as global warming and ocean acidification [1]. CO_2 capture and storage (CCS) technology is currently one of the most promising solutions to control CO_2 emissions and has been commercially demonstrated. CCS mainly includes 3 steps: CO_2 capture, transportation, and storage. Compared with the CO_2 transportation and storage steps, the cost of CO_2 capture accounts for 60 ~ 70% of the total cost of CCS [2]. Therefore, it is urgent to develop cost-effective CO_2 capture technology. The post-combustion amine scrubbing is currently the most mature CO_2 capture technology on the industrial scale. However, several issues related to this technology limit its large-scale application, including high regeneration energy (efficiency penalty of 9.9 ~ 14.0) [3], high cost ($52 ~ 77/ton) [4], solvent degradation [5], corrosiveness [6], and reaction with other compounds in the flue gas (such as O_2, SO_2, NOx, and fly ash) [7,8].

In the past few years, the utilization of solids to capture CO_2 has been considered a more practical and inexpensive alternative [9-12]. The calcium looping (CaL) process is an emerging and promising CO_2 capture technology based on the reversible carbonation/calcination reaction [13,14].

Carbonation:

$$CaO(s) + CO_2(g) \rightarrow CaCO_3(s), \Delta H_{r,298K} = -178kJ \bullet mol^{-1} \quad (1)$$

Calcination:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g), \Delta H_{r,298K} = +178kJ \bullet mol^{-1} \quad (2)$$

Compared with other CO_2 capture technologies, such as amine scrubbing technology, CaL technology has the following advantages: (1) Natural limestone or dolomite, which is abundant and environmentally friendly, can be used as the raw material to prepare CaO; (2) The CO_2 absorption capacity of CaO is relatively high, reaching 0.786 gCO_2/gCaO; (3) The energy consumption of CaL technology is relatively low

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