



Strategies to improve CaO absorption cycle stability and progress of catalysts in Ca-based DFMs for integrated CO₂ capture-conversion: A critical review

Pengchao Zang^a, Jiyun Tang^{a,b}, Xiaoyang Zhang^a, Lin Cui^a, Juan Chen^a, Pei Zhao^a, Yong Dong^{a,*}

^a National Engineering Laboratory for Reducing Emissions from Coal Combustion, Engineering Research Center of Environmental Thermal Technology of Ministry of Education, Shandong Key Laboratory of Energy Carbon Reduction and Resource Utilization, School of Energy and Power Engineering, Shandong University, Jinan, Shandong 250061, China

^b School of Energy and Control Engineering, Changji University, Changji 831100, China

ARTICLE INFO

Editor: Chao He

Keywords:

CaO-based
CO₂ capture
In situ CO₂ capture-conversion
Dual-function materials
Process design
Industrial applications

ABSTRACT

The capture or utilization of CO₂ from industrial sources (i.e., fossil-fueled power plants, cement plants and industrial furnaces) is the priority for achieving carbon reduction. The calcium looping (CaL) process is a promising technology for CO₂ capture, where CaO exhibits excellent potential for high temperature CO₂ absorbent applications in terms of low cost, abundant storages and high theoretical capture capacity. In addition, integrated CO₂ capture-conversion (ICCC) technology is an emerging integrated process that achieves cost reduction and efficiency by capturing CO₂ directly from industrial flue gases using Ca-based bifunctional materials (i.e., absorbents and catalysts, DFMs) and simultaneously converting them into high value-added chemicals. In this work, the research progress of Ca-based materials as CO₂ absorbents and bifunctional materials are respectively reviewed. The sintering of CaO during the carbonation/calcination cycle caused its absorption capacity to decrease rapidly with the number of cycles, thus limiting the application of Ca-based absorbents. The first section summarizes the incorporation of alkali metals, the optimization of inert components, and the synthesis of highly porous structures to slow down the sintering of CaO particles. Meanwhile, the effects of reaction temperature (carbonation and calcination temperatures) and reaction atmosphere (SO₂, H₂O and concentrated CO₂) on the sintering of CaO pellets are also reviewed. Furthermore, in response to the research progress of ICCC process, the second section analyses and discusses the influence of reaction conditions such as temperature and impurity gases (i.e., NO_x, SO_x, H₂O and O₂, etc.) in the flue gas on ICCC for guidance of future research. Subsequently, the development of Ca-based DFMs categorized by the catalytic component (i.e., Ni, Ru, etc.) is reviewed, including their performance and potential reaction mechanisms. The interaction mechanism between catalyst and absorbent in Ca-based DFMs is reviewed. Finally, the future development of Ca-based CO₂ absorbents and bifunctional materials are envisaged. It is also hoped that this work will help researchers to provide effective guidelines in the field of the preparation and reaction conditions of Ca-based materials.

1. Introduction

Carbon dioxide (CO₂) is one of the major anthropogenic greenhouse gases in the atmosphere [1,2]. Since the industrial revolution, the excessive use of fossil fuels such as oil, coal, and natural gas has resulted in large emissions of CO₂, leading to an increase in the greenhouse effect [3]. According to the latest data monitored by the U.S. Earth System Research Laboratory (ESRL), the global concentration of CO₂ in the

atmosphere has reached 420 ppm as of April 2023, an increase of 8.5% from the 2010 level of 387 ppm [4]. Furthermore, the BP's forecasts that the CO₂ emissions will reach 36.0 billion tons by 2040 [5]. The fossil fuel as the dominant industrial energy source will not be largely replaced in the foreseeable future. CO₂ capture is a necessary precursor to carbon capture, utilization, and storage (CCUS) [6,7]. In particular, the CO₂ capture from industrial sources is the paramount importance. The current industrial source CO₂ capture methods can be categorized as

* Corresponding author.

E-mail address: dongy@sdu.edu.cn (Y. Dong).

<https://doi.org/10.1016/j.jece.2023.111047>

Received 26 June 2023; Received in revised form 15 September 2023; Accepted 17 September 2023

Available online 19 September 2023

2213-3437/© 2023 Published by Elsevier Ltd.