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Synthesis of CaO-based Sorbent from Biomass for CO₂ Capture in Series of Calcination-carbonation Cycle

Mustakimah Mohamed, Suzana Yusup* and Mohamad Azmi Bustam

^aBiomass Processing Laboratory, Center of Biofuel and Biochemical Research, Chemical Engineering Department, Universiti Teknologi PETRONAS, 32610 Bandar Seri Iskandar, Perak, Malaysia

Abstract

This paper described CO₂ capture performance of CaO-based sorbents which were derived from biomass mixture within 9 cycles of calcination-carbonation conducted in TGA. The study utilized commercial sorbent to configure the suitable calcination and carbonation condition as a reference to synthesis biomass-derived sorbent. Calcination was conducted at 850°C in pure N₂ atmosphere for 20 min while carbonation occurred at 800°C in pure CO₂ environment for 30 min. Cockerle shells (CS) were utilized as the main precursor to synthesize CaO and its capture performance was enhanced by adding 20 wt.% biomass of rice husk (RH), empty fruit bunch (EFB) and palm kernel shell (PKS). Biomass addition to CS has increased CO₂ capture capacity of the derived sorbents. The highest CO₂ captured was obtained by fresh sorbent of CS with EFB which is 8% higher than non-mixed CS sorbent. However after regeneration, CS with CBA sorbent illustrated the highest capture capacity among all sorbents at every cycle. The derived CS with EFB sorbent also demonstrated the most cyclic-stable material due to minimum loss of CO₂ captured capacity. Overall, application of biomass-derived CaO-sorbent in a series of calcination-carbonation cycle is promising CO₂ capture development.

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Keywords: CaO-based sorbent; CO₂ sorption; cockle shell; rice husk; empty fruit bunch; coal bottom ash

1. Introduction

CaO-based material derived from biomass has been an effective substance in CO₂ sorption and separation activity [1]. The material is technically feasible, costly effective and advantageous to certain extent in capturing CO₂ [2]. CaO-

* Corresponding author. Tel.: +6-05-368-7642; fax: +6-05-365-7648.
E-mail address: drsuzana_yusuf@petronas.com.my

based sorbent demonstrates CO_2 sorption and desorption process via carbonation and calcination cycle [3]. Carbonation is a highly exothermic reaction but with proper heat integration, this heat can be channelled for its endothermic sorbent regeneration step which is calcination [4]. Yu et al. [5] mentioned that CO_2 released due to regeneration step is meant to sent for sequestration or storage while Blamey et al. [6] and Ridha et al. [7] stated that the spent sorbent is proven to be suitable for cement industry. Fig. 1 demonstrated the process of CO_2 capture and sorbent generation via calcination-carbonation cycle of CaO -based sorbent. Broda et al. [8] mentioned that Ca -based sorbents through calcination and carbonation reaction has been an emerging CO_2 capture technique due to some limitation of current capture technology such as CO_2 scrubbing using amine-based solvent. Calcium looping system (CaL) is claimed to operate at 38% of the total cost operation using mono-ethanol amine (MEA) solvent to capture CO_2 [9].

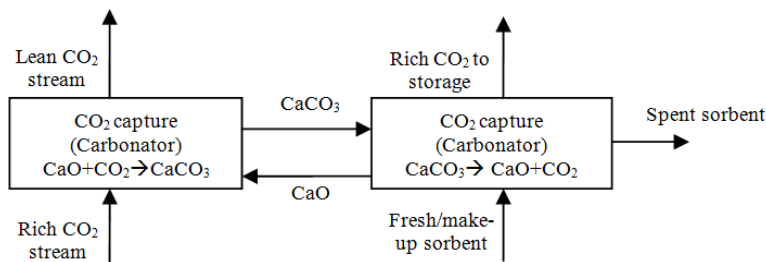


Fig. 1: Schematic diagram of CO_2 capture via calcination-carbonation cycle using CaO -based sorbent

Sorbents that been derived from biomass or natural sources has high initial CO_2 carrying capacity yet it experiences rapid loss in with increasing number of reaction cycles [4,7] and the materials are mechanically fragile which led to excessive sorbent loss [7]. Hence the challenges lie on improving its capture capacity along with reaction cycles. Improve the sorbent synthesis method and synthesized using mixture of oxide has been listed by Wang et al. [10] as the approaches to enhance CO_2 sorbent performance. In addition, wet mixing as synthesis method and thermal pre-treatment such as high calcination temperature (900°C) and hydration at 70°C are also described to improve sorbent cyclic stability [4].

Wang et al. [10] mentioned that CaO -based sorbent with silica support exhibits stable CaO conversion during reaction cycles. CaO -based sorbent with 10wt% silica reached stable conversion of more than 0.6 which was higher than the untreated sorbent. Increased of alkaline ions such silica and alumina has able to increase CO_2 capture reactivity [11] since it enhances cation–quadrupole interaction with CO_2 [12]. Alkaline earth metal atoms have high polarizabilities and dispersion potentials on the material surface [13].

Lee et al. [14] mentioned that pozzalonic reaction can occur when $\text{SiO}_2 / \text{Al}_2\text{O}_3$ is mixed with $\text{Ca}(\text{OH})_2 / \text{CaO}$ using alkaline water producing hydrate compounds which have high surface area and promotes CO_2 sorption. Biomass such as empty fruit bunch (EFB), rice husk (RH) and coal bottom ash (CBA) contained large portion of alumina and silica. Lee et al. [14] found coal ash to contain mainly silica (40-60wt.%) and alumina (15-20wt.%). Jayaranjan et al. [15] and EPRI [16] also recorded that coal ash to contain silica and alumina and yet it also composed of CaO which and lignite coal recorded the highest range of CaO composition which is within 8/6-45.1%.

This paper summarized the effect of calcination dwelling time and addition of biomass that contained SiO_2 and Al_2O_3 into CaO -based sorbent towards the sorbent capture capacity and cyclic stability.

Nomenclature

m_0	initial mass (mg)
m_t	current mass (mg)
m_f	final mass (mg)

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