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Full Length Article

A study on the CO_2 capture and attrition performance of construction and demolition waste

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ABSTRACT

CaO-based sorbent deactivation is one of challenges to develop CaO-based chemical looping technology. The replacement of non-renewable natural or expensive synthetic CaO-based sorbents with cheap and environmental CaO-based waste sorbents is an effective way to overcome this challenge. As high CaO content, construction and demolition waste (CDW) has ability to capture CO_2. Due to the rapid development of cities, a great deal of CDW is produced every year. According to the characteristics of CDW, six components were selected in this paper. From the initial CO_2 carrying capacity, hydrated limestone had the highest initial CO_2 carrying capacity, about 0.592 g CO_2/g sorbent in TGA and 0.414 g CO_2/g sorbent in fluidized bed system, followed by limestone, cement-based limestone, hydrated cement, cement-based sand, cement raw and sand. For multiple carbonation-calcination cycles, cement played a positive role in maintaining high cyclic CO_2 carrying capture. Hydration degree and free lime content increased with the increase of hydration time, which improved the CO_2 capture performance of CDW. For cement-based sorbents, evidence from this study suggested that extending hydration time played a positive role in improving the attrition resistance and maintaining the initial specific surface area in fluidized bed system.

1. Introduction

CDW is divided into three kinds, such as CDW from the construction of building, CDW from the renovation of the building, and CDW from the demolition of building [1]. Due to the rapid development of cities, numerous abandoned buildings need to be demolished every year, so CDW from the demolition of building is the main source of CDW. The National Development and Reform Commission (NDRC) estimated that the amount of CDW in China is about 1 billion tons in 2013 – six times the amount of Municipal Solid Waste (MSW) [2].

The composition of CDW is complex, and the total proportion of dust, rubble and concrete is over 60%, as shown in Table 1. Some CDW composition, such as steel and wood, could be recycled directly or by simple recycle ways, but the other compositions, such as concrete, crushed stone and clay, are difficult of recycle. Washing can separate concrete from the mixture, which comprise of concrete, crushed stone and clay. If those compositions were removed, such as steel, wood, glass and clay, the fraction of concrete could reach to 40–50%, and become the main composition of CDW. Stacking and landfills are the main methods for treating CDW. But these methods waste land resources and bring environmental pollution. How to use CDW become a key problem for the sustainable development of cities.

CaO-based sorbent deactivation is one of challenges to develop CaO-based chemical looping technology [4,5]. Like fossil fuels, limestone is a non-renewable mineral resource. With the great use of human beings, its reserves will be reduce.

To prevent the CO_2 carrying capacity of sorbent from decling, there has been an increasing interest in the development of synthetic sorbents. One of main technologies is developing synthetic sorbents with high specific surface area without adding additional inert solid matrix [6,7]. Another main technology is develping synthetic sorbents with high melting point framework support [8,9]. Lu et al. [10] compared the CO_2 carrying capacity of $Ca(NO_3)_2{\cdot}4H_2O$, $Ca(OH)_2$, $CaCO_3$ and $Ca(CH_3COO)_2{\cdot}H_2O$, and the resluts indicated that the specific surface area of $Ca(CH_3COO)_2{\cdot}H_2O$ was highest, and the CO_2 carrying capacity still kept to 0.49 g CO_2/g sorbent after 27 cycles [10]. After the modification of organic acid, the CO_2 carrying capacity of sorbent is improved, but the modified sorbnets were easy to hygroscopic. Lu et al. [11]studied the effect of additional inert solid matrix, such as Si, Co, Ti, Cr, Ce and Zr, on the CO_2 carrying capacity of synthetic sorbents by flam spray

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Table 1
The compositions of CDW from the demolition of building [3].

Component	%	Component	%
Dust	25–38	Metal	3–5
Rubble	20–27	Sand	1–2
Concrete	5–15	Asphalt	0–1
Wood	8–12	Glass	0.3–0.8
Reinforced concrete	7–12	Others	4–5
Brick	4–6		

pyrolysis (FSP). The results proved that the most robust nanosorbent was produced when the atomic ratio of Zr/Ca equaled to 3:10 [11]. Martavaltzi et al. [12] pointed out that $CaO\text{-}Ca_{12}Al_{14}O_{33}$ could be synthesized by the liquid mixing method, and the initial CO_2 carrying capacity of $CaO\text{-}Ca_{12}Al_{14}O_{33}$ was 0.35 g CO_2/g sorbent, after 30 cycles, still kept to 0.30 g CO_2/g sorbent. But the price of Co, Ti, Cr, Ce, Zr and Al_2O_3 were expensive. In the process of artificial synthesis, it is need to invest a lot of professional equipment, such as spray drying device, stirring device and sedimentation tank, but also consume high quality limestone, clean water and energy. Therefore, the cost of synthetic process is an key restraining factor for the development of synthetic sorbents. Unconsidering the cost and complexity of synthetic process, developing synthetic sorbents is an way to improve the CO_2 carrying capacity at high temperature cycle.

So replacement of non-renewable natural or expensive synthetic CaO-based sorbent with environmental and cheap CaO-based waste sorbents is an effective way to overcome this challenge [13,14]. As high CaO content, CDW has ability to capture CO_2 [15]. CDW had the advantages of extensive source and low cost. So CDW could be used as a cheap CaO-based sorbent to replace the non-renewable natural or expensive synthetic CaO-based sorbents.

Some authors has investigated the capture efficiency of CDW and provided quantitative information [15–17]. Moghtaderi et al. [15] confirmed that the CO_2 capture efficiency of CDW could reach to 56.4%, and the hydrogen concentration of flue gas could reach to 49% when CDW was used as sorbent. Pathi et al. [16] proved that the cement raw meal also could be used as sorbent, but there were interactions between lime and the other components. However, few investigations focus on the attrition of CDW. CaO-based sorbent needs be circulated between several fluid bed reactors in the CaO-based chemical looping technology, which wear sorbent particles [18]. Attrition resistance is a key factor in the development of the CaO-based chemical looping technology.

The hydration of cement is an essential construction link. The compressive strength of concrete was improved by the hydration of cement [19]. The hydration of cement is a physical and chemical process. The loose cement raw powder could be changed into cement paste by the hydration of cement, and then it bonds with a variety of coarse or fine aggregates to form concrete. Hydrated time is an important factor for improving the compressive strength of concrete [20]. Hydration time is important for the formation of concrete. Up to now, far too little attention focus on the effect of hydration time on the CO_2 capture performance of concrete.

Additionally, if CDW was used as sorbent, some components with weak CO_2 carrying would be present. The total CO_2 carrying capacity of CDW would reduce with the remian of those components in CDW. So one of the greatest tests is confirm the CO_2 carrying capacity of each component in CDW.

One purpose of this research was to investigate the performance of original components in CDW. Another aim of this research was to study the influence of hydration process on the CO_2 capture and attrition performance of CDW. There are several important areas, which contributes to the CO_2 capture and attrition performance of CDW for the CaO-based chemical looping technology.

2. Experimental section

2.1. Materials

Fig. 1 shows the selecting principle of material. As presented in Fig. 1, six samples were selected in this paper. Concrete is composed of cement raw, sand and gravel. Sand and cement raw as basic materials of concrete was selected in this paper. Cement raw (PC 32.5) is made in Shaanxi Qinling Cement (Group) Co., Ltd., and widely used in engineering fields. Cement-based sand and hydrated cement as the model materials of concrete was applied. Limestone as a representative sorbent was selected. To reveal the effect of cement on the performance of limestone, cement-based limestone was selected. As hydration was a necessary way to obtain cement-based limestone, the hydrated limestone was selected.

In this paper, the basic materials including sand, cement raw and limestone were crushed by grinder (5E-PC1 × 100, Changsha Kaiyuan Instruments Co., Ltd.). Those crushed particles were screened by a sieve shaker (5E-SS200, Changsha Kaiyuan Instruments Co., Ltd.), and those particles with the size of 0.075–0.10 mm were selected as raw materials for producing concrete. It should be noted that the preparation of CS was based on mass ratio of SA:CR equaled to 1:1, and the preparation of CL was based on the mass ratio of LE:CR equaled to 1:1. Those particles was mixed by oscillator (THZ-82, Changzhou Gude Instrument Co., Ltd.) with the rotation rate of 300 r/min for 12 h. Then those mixtures was placed in the rectangular molds, and added distilled water into molds and stirred. During the hydration process, the surface of water was 10 cm higher than that of silicate colloid. Following, the samples placed into ventilation kitchen with hydrated temperature of 25–65 °C for 4–12 days, then those samples were dried in a drying oven at the

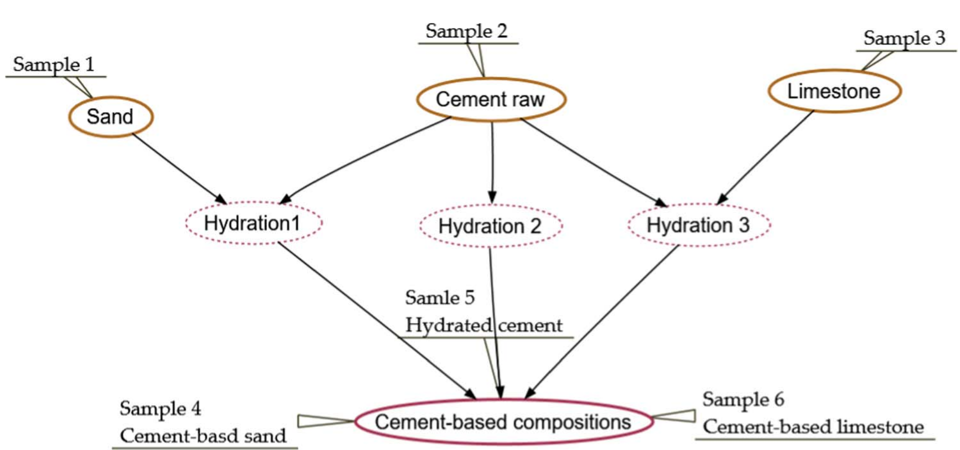

Fig. 1. The selecting principle of material.