High temperature fixation of CO\textsubscript{2} from catalytically plastic pyrolytic furnace

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Abstract: The CO\textsubscript{2} capture from industrial emission source is a crucial theme for sustainable energy development. This study focus on CO\textsubscript{2} capture at elevated temperature conditions, which was applied on catalytic pyrolysis of plastic solid waste (PSW) process. Decomposition of plastics by catalyst occurred at 400-500 °C, accompanied with about 6.7 v\% hot CO\textsubscript{2} in flue gas. Capturing CO\textsubscript{2} by Ca/Al solid sorbents at 700 °C was performed by Thermogravimetric (TG) analysis and a fixed-bed reactor. The result showed that capture weight was 40wt.% and removal rate was higher than 80%. It is helpful to advanced development for PSW-like carbon recycle technologies.

Keywords: Plastic, Pyrolysis, CaO, CO\textsubscript{2} capture.

1. Introduction

Non-Recycled Plastics (NRP), plastic waste have heating value about 38 MJ/kg, which is approximately 80% of virgin resins’ heating values. Using NRP as cyclic materials via pyrolysis of plastic solid waste (PSW) producing fuel oil provides economic potentiality, compared to disposal or landfill [1]. Pyrolysis helps anaerobic cracking polymer constituents by catalyst at 400-500 °C under assisted fuel combustion, while accompanied with considerable amount of hot CO\textsubscript{2} emission from combustion gas. The critical reviews [2] indicated that CO\textsubscript{2} capture technology by solid sorbents of CaO has continually developed.

2. Experimental

The CO\textsubscript{2} sorbent [3], 7Ca/Al material was prepared by co-precipitating Ca\textsuperscript{2+} and Al\textsuperscript{3+} in an alkaline solution. Fig. 1 illustrates CO\textsubscript{2} capture item in a pyrolysis of plastic solid waste (PSW) process. The PSW was thermal decomposition in a reactor and the flue gas was sampling and analyzed by a Gas Chromatography (GC, SHIMADZU Tracera GC-2010 Plus A+BID-2010 Plus) and gas analyzer (MRU VARIO plus), which respectively indicated 6.6% and 6.7% CO\textsubscript{2} of combustional flue gas (Table 1). The capture capacity, W (mass%, g CO\textsubscript{2}/g sorbent), is the mass gained relative to the sorbent mass during sorption. The CO\textsubscript{2} capacity weight, W(t), was also estimated from the molar volume at 25 °C using the ideal gas equation. Therefore, the CO\textsubscript{2}-specific sorption in the i\textsuperscript{th} cycle, C\textsubscript{i}, was obtained from integrates the CO\textsubscript{2} volume difference (∆VCO\textsubscript{2}) over time assuming 80~90% breakthrough at the column outlet.

| Table 1. Gas composition including pyrolytic flue gas. |
|---------------------------------|--------|--------|--------|--------|--------|--------|--------|
| Gas sources, %                  | CO\textsubscript{2} | CO     | H\textsubscript{2} | CH\textsubscript{4} | O\textsubscript{2} | N\textsubscript{2} | Sum     |
| flue gas                        | 6.7    | 0      | 0.1    | 0.2    | 11.2   | 81.8    | 100     |
| exp. syngas                     | 17     | 47     | 34     | 2      | 0      | 0       | 100     |
| exp. gas                        | 100    | 0      | 0      | 0      | 0      | 0       | 100     |

Figure 1. View of CO\textsubscript{2} capture in PSW process.

3. Results and discussion

The capturing potential using Ca/Al sorbent exhibited 39~46 wt% capacity at 6.7~100% CO\textsubscript{2} under 700~750 °C. For CO\textsubscript{2} capture, CaO-based sorbents with stabilized agent such as Al exhibited high initial
conversion 67% at 650°C [4]. According our previous results, 7Ca/Al sorbent had about 88 wt.% CaO, also indicating 67% CaO conversion at 100% CO₂ in 750°C. A fixed-bed reactor with a column loaded with Ca/Al granules was employed to investigate CO₂ sorption capacity using NDIR monitoring. Based on the TG result, the test conditions include inlet 40% CO₂ at 750 °C. Fig. 2(a) is a plotting for the temporal variation in CO₂ concentration throughout 10 cycles. Analyzing the breakthrough curves, we determined that Ca/Al granules effectively capture CO₂ up to the break point, followed by rapid reversion to the feed-gas condition. The breakthrough time was ~80 min in the first cycle, reducing to about 40 min after 10 cycles, implying that the stability of the sorbent had deteriorated after repeated cycles. The removal rate was higher than 80–90% before saturation capacity at suitable sorption time during multicycles. As usual, 90% CO₂ removal kept 75 min at 1st cycle then gradually declined about 15% at continue test. It is estimated that 10th CO₂ capture weight maintained approx. 76% of initial capacity at 10 cycles. Granule Ca/Al sample provides capture potentiality in reactor.

Besides, the simulated gas including about 6.7% CO₂ was prepared and tested via test rig. As shown in Fig. 2(b). From IR analysis, there was no leakage between gas tank with reactor and the inlet CO₂ content maintained at about 6.7%. The capture test was executed via Ca/Al capturing flue gas at 700 °C conditions, obtaining 90% removal maintained about 1 hundred minutes from simulated gas. This CO₂ sorption weight was 16-20 wt% by ideal gas mole volume calculation. Further study is necessary in order to understand the kinetics and mechanism at which achieve the maximum capture weight during repeated cycles.

![Figure 2. (a) the CO₂ capture breakthrough curve at ten cycle in a fixed-bed reactor. (b) CO₂ capture curve in simulated gas by test rig.](image)

**4. Conclusions**

The feasibility of CO₂ capture using Ca/Al material has been examined using a TG analysis and a fixed-bed test rig. The results showed that Capturing potential using Ca/Al sorbent exhibited 39–46 wt% capacity at 6.7~100% CO₂ under 700~750 °C. In a fixed-bed reactor, the removal rate was higher than 80–90% before saturation capacity at suitable sorption time during multicycles. Beside, the test rig was used to estimate the capture capacity of simulated gas source, obtaining CO₂ sorption weight of 16-20 wt% and 90% removal. It demonstrates the potentiality toward advanced development for PSW-like carbon recycle technologies. The CO₂ capture performance can be advanced evaluated by connection of sorbent reactor with downstream duct of pyrolysis furnace from industrial application.

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**References**