High temperature fixation of CO_2 from catalytically plastic pyrolytic furnace

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Abstract: The CO_2 capture from industrial emission source is a crucial theme for sustainable energy development. This study focus on CO_2 capture at elevated temperature conditions, which was applied on catalytic pyrolysis of plastic solid waste (PSW) process. Decomposition of plastics by catalyst occured at 400-500 ℃, accompanied with about 6.7 v% hot CO_2 in flue gas. Capturing CO_2 by Ca/Al solid sorbents at at 700 ℃ 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_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 ℃ under assisted fuel combustion, while accompanied with considerable amount of hot CO_2 emission from combustion gas. The critical reviews [2] indicated that CO_2 capture technology by solid sorbents of CaO has continually developed.

2. Experimental

The CO_2 sorbent [3], 7Ca/Al material was prepared by co-precipitating Ca^{2+} and Al^{3+} in an alkaline solution. Fig. 1 illustrates CO_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_2 of combustional flue gas (Table 1). The capture capacity, W (mass%, g CO_2/g sorbent), is the mass gained relative to the sorbent mass during sorption. The CO_2 capacity weight, W(t), was also estimated from the molar volume at 25 ℃ using the ideal gas equation. Therefore, the CO_2-specific sorption in the *i*th cycle, C_i, was obtained from integrates the CO_2 volume difference (ΔVCO_2) over time assuming 80~90% breakthrough at the column outlet.

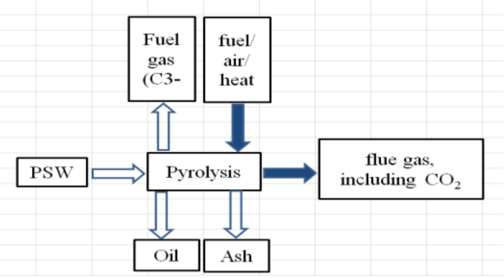

Figure 1. View of CO_2 capture in PSW process.

Table 1. Gas composition including pyrolytic flue gas.

Gas sources, %	CO_2	CO	H_2	CH_4	O_2	N_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

3. Results and discussion

The capturing potential using Ca/Al sorbent exhibited 39~46 wt% capacity at 6.7~100% CO_2 under 700~750 ℃. For CO_2 capture, CaO-based sorbents with stabilized agent such as Al exhibited high initial conversion 67% at 650℃ [4]. According our previous results, 7Ca/Al sorbent had about 88 wt.% CaO, also indicating 67% CaO conversion at 100% CO_2 in 750℃. A fixed-bed reactor with a column loaded with Ca/Al granules was employed to investigate CO_2 sorption capacity using NDIR monitoring. Based on the TG result, the test conditions include inlet 40% CO_2 at 750 ℃. Fig. 2(a) is a plotting for the temporal variation in CO_2 concentration throughout 10 cycles. Analyzing the breakthrough curves, we determined that Ca/Al granules effectively capture CO_2 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% CO_2 removal kept 75 min at 1st cycle then gradually declined about 15% at continue test. It is estimated that 10th CO_2 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% CO_2 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 CO_2 content maintained at about 6.7%. The capture test was executed via Ca/Al capturing flue gas at 700 ℃ conditions, obtaining 90% removal maintained about 1 hundred minutes from simulated gas. This CO_2 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.

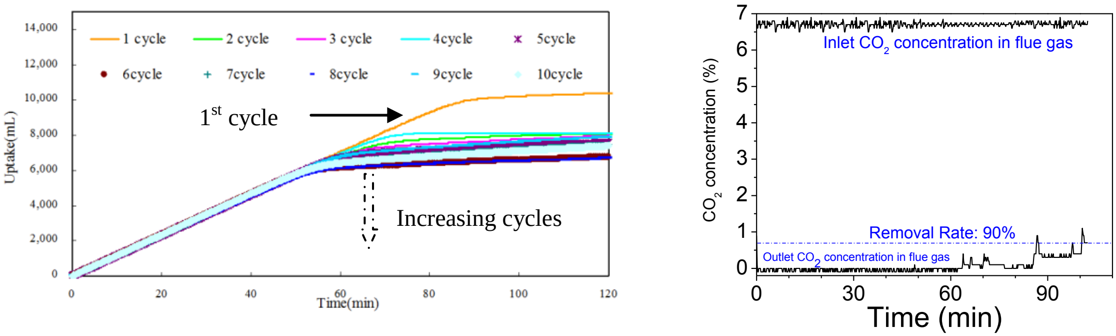

Figure 2. (a)the CO_2 capture breakthrough curve at ten cycle in a fixed-bed reactor. (b)CO_2 capture curve in simulated gas by test rig.

4. Conclusions

The feasibility of CO_2 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% CO_2 under 700~750 ℃. 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 CO_2 sorption weight of 16-20 wt% and 90% removal. It demonstrates the potentiality toward advanced development for PSW-like carbon recycle technologies. The CO_2 capture performance can be advanced evaluated by connection of sorbent reactor with downstream duct of pyrolysis furnace from industrial application.

5. Acknowledgments

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