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The effect of CO on coal-biomass co-gasification with CO₂

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HIGHLIGHTS

• Coal-biomass blended char was gasified with CO₂ in the presence of CO.

• Inhibition effect of CO on char-CO₂ gasification was studied.

• Langmuir-Hinshelwood (L-H) equation was used to describe the CO inhibition effect.

• Random pore model was used to interpret the carbon conversion data.

• L-H kinetic parameters were obtained and expressed in an Arrhenius equation form.

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ABSTRACT

In this study, co-gasification of coal and biomass chars with CO_2 in the presence of CO was investigated at three different temperatures: 850, 875, and 900 °C. A coal-biomass (bituminous-pineapple sawdust) mixture with a mass ratio of 1:1 was used for devolatilization and co-gasification. Random pore model was employed to determine the kinetic coefficient from experimentally obtained carbon conversion data. The Langmuir–Hinshelwood (L–H) equation, which has been widely used in literatures to describe the relationship between kinetic coefficient of the gasification and partial pressures of reacting gases, effectively represented the inhibition effect of CO on char– CO_2 gasification. The kinetic parameters of the L–H equation were acquired from the experimental data. The activation energy (*E*) and pre-exponential factor (*A*) of each kinetic parameter of L-H equation were obtained using the Arrhenius equation. CO inhibition effect was more powerful in the Char- CO_2 co-gasification of the mixed sample compared to those in the unmixed samples. Further, for each sample, the inhibition effect was stronger at lower temperature owing to a smaller number of active sites.

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1. Introduction

Coal and biomass co-gasification is an effective approach to reducing CO_2 emissions and fossil fuel dependence [1,2]. Since the physical and chemical characteristics of coal are significantly different from those of biomass, the design of a gasifier for cofiring of coal and biomass requires an understanding of cogasification mechanisms [3,4]. Investigations on co-gasification of coal-biomass mixed char in CO_2 or H_2O atmosphere have been carried out by different researchers [1,5–8]. In a real gasifier, however, existence of H_2 and CO affects the char gasification and some studies have investigated this issue for one hundred percent coal or biomass samples [9–14]. However, the effects of existence of H_2 and CO on coal-biomass co-gasification have not yet been studied

* Corresponding author. E-mail address: hwangjh@yonsei.ac.kr (J. Hwang). satisfactorily. Our previous study investigated the coal-biomass co-gasification in H_2O-H_2 atmosphere and it was discovered that inhibition effect of H_2 was more powerful in the mixed sample compared to those in the unmixed samples [15].

The present study, as a continuation of our previous study [15], obtained the kinetic parameters of the Langmuir–Hinshelwood (L–H) equation for coal–biomass co-gasification with CO_2 considering CO existence. To determine the kinetic coefficient from experimentally obtained carbon conversion data, random pore model (RPM) was employed, as in our previous studies [15–18].

Preliminary tests were conducted to determine the experimental temperature range, and it was found that for all the char samples, gasification with CO_2 at temperatures lower than 900 °C was governed by the chemical control regime. Accordingly, in this study, all char samples were gasified with CO_2 at 850, 875, and 900 °C after the pyrolysis process. The results of preliminary tests, along with the properties of coal and biomass, the experimental











Fig. 2. Plots of (a) $1/k_{CO2}$ vs. $1/P_{CO2}$ and (b) lnk_i vs. 1/T.

Table 1	
Kinetic	parameters

		1101) 715 (3)	E_5 (KJ IIIOI)	$A_6(S)$	E_6 (KJ mol ⁻¹)
Coal 2 2.31 Biomass:Coal = 1:1 2 1.23 Biomass 2 8.04	$\begin{array}{ll} 1 \times 10^{21} & 533 \\ 3 \times 10^5 & 162 \\ 4 \times 10^7 & 212 \end{array}$	$\begin{array}{c} 6.68 \times 10^{20} \\ 8.23 \times 10^{-1} \\ 1.35 \times 10^{3} \end{array}$	429 43 38	$\begin{array}{c} 2\times 10^2 \\ 1.1\times 10^{-1} \\ 2.1\times 10^{-6} \end{array}$	-25 -105 -189

setup, and the kinetic modeling, are given in the Supplementary Material (SM).

Based on the L–H mechanism, k_{CO2-CO} can be expressed as

$$k_{\rm CO_2-CO} = \frac{K_4 P_{\rm CO_2}}{1 + K_5 P_{\rm CO_2} + K_6 P_{\rm CO}} \tag{1}$$

where K_4 , K_5 , K_6 , P_{CO2} , and P_{CO} are, respectively, three kinetic parameters and partial pressures of CO₂ and CO. In the experiments performed without CO, Eq. (1) changes to

$$k_{\rm CO_2} = \frac{K_4 P_{\rm CO_2}}{1 + K_5 P_{\rm CO_2}} \tag{2}$$

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