Characteristics of Low Temperature Co-pyrolysis and Co-gasification of Biomass and Coal

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SYNOPSIS
Characteristics of co-pyrolysis and co-gasification at low temperature were examined by using a downdraft fixed bed reactor. Steam was used as gasifying agent to gasify mixtures of coal and biomass in atmosphere of argon. The type of biomass and coal as well as its mixing weight ratio, temperature, and gasifying agent were varied. The efficiency of pyrolysis and gasification process was investigated by measuring amount of gas and char produced. The result shows that mixing coal and biomass as feedstock gave significant improvement of gas production compared with a single biomass or coal as feedstock. Biomass can promote gas production of coal and promoting effect depends on the type of biomass itself.

1. Introduction
Recently, co-pyrolysis and co-gasification of coal and biomass has been studied extensively due to its advantages, such as low carbon footprint to the environment, reduce problems caused by sulfur, and also reduce operational problem due to tar production [1-3]. Another attractive point of co-pyrolysis and co-gasification is the synergetic effect of coal and biomass so that mixing them in the feedstock could gives higher gas production than when they were processed separately [1]. However, most of recent studies did pyrolysis and gasification at relatively high temperature. In the present study, mixture of coal and several kinds biomass with varying content were pyrolyzed and gasified at low temperature in order to investigate possibility and characteristics of mild temperature operation. The presence of synergetic effect between coal and biomass was investigated by comparing the gas production result of mixed sample with the gas production from single sample.

2. Experiment
Three kinds of biomass (Japanese cedar wood C5ryptomeria japonica, brown seaweed Sargassum horneri and rice straw) and two kinds of coal (Chinese bituminous SS106 and Adaro lignite coal) were selected as feedstock for pyrolysis and gasification. The coals were obtained from AIST coal bank while biomasses were obtained from local area. All feedstock were pyrolyzed separately as well as in the mixed state. The weight ratio of biomass and coal in the mixed sample were varied at 0, 0.5, and 1 on sample weight basis.

Figure 1 shows the schematic diagram of pyrolysis/gasification experimental set-up. A fixed bed downdraft reactor was utilized as pyrolyzer/gasifier. 1 gram of sample were put in sample holder and pyrolyzed at three different temperatures (500, 550, and 600 °C). Argon was used as carrier gas with flow of 50 ml/min. For steam gasification process, carrier gas passed through steam generator which produced 0.09 ml/min (water based) saturated steam at 90 °C. Ribbon heater was used to avoid steam condensation along the gas line. Volatile products come out from the bottom of reactor while char and ash remain inside the reactor. Liquid products such as tar and oil were collected in ice bath. To ensure no moisture in the gas, gas product was passed through gas purifier (contained CaCl2 and silica gel) and then collected in a gas bag. Amount of CO2, CH4, CO, and H2 in the gas bag were analyzed using gas chromatograph (Agilent 7890A).
3. Results and Discussion

Figure 2 shows CO₂, CH₄, CO, and H₂ gas production during pyrolysis of various feedstock types at 600 °C. Lignite coal produced more gas than SS106 coal since it contains more volatile matter. The same reason also causes gas production of Japanese cedar is less than seaweed or rice straw. However, gas from seaweed (which contains slightly less volatile matter) is higher than rice straw. This result happens because seaweed has more alkali metal on its ash. Alkali metal is known to have catalytic effect on gasification process.

Figure 3 shows total gas production from mixture of lignite coal and three kinds of biomass when pyrolyzed with and without steam as gasifying agent. Amount of coal and biomass in each sample were equal (biomass-to-coal ratio equal to 1). All samples were pyrolyzed and gasified at 600 °C. In general, using gasifying agent will promote gas production. It is shown from the graph that gas production while steam were used is higher than without steam. Significant amount of gas production improvement was observed when coal mixed with seaweed. Steam can improve gas production of coal and seaweed mixture significantly due to the presence of alkali metal on it. Alkali metal can catalyze steam gasification as well as tar reforming [4].

Figure 4 shows the amount of gas produced only from coal when it pyrolyzed together with biomass by assuming that gas produced from biomass was proportionally linear. The result shows that gas production from coal is increasing respect to biomass content in the sample. Synergetic effects as reported by Collot et al. [1] were observed in this study. Large amount of alkali metal in biomass ash could catalyze not only the biomass itself but also coal in the sample. Higher content of alkali metal gives better catalytic effect. Therefore, seaweed and rice straw can promote coal gas production more significant than cedar wood.

![Fig.2 Gas production from pyrolysis of various feedstock types](image1)

![Fig.3 Comparison of total gas production from mixture of coal and various biomasses with and without steam as gasifying agent](image2)

![Fig.4 Gas production from coal only after pyrolysis with seaweed, rice straw, and cedar wood](image3)

4. Conclusions

Mixture of low-rank coal and three kinds of biomass were pyrolyzed and gasified with steam to investigate the effect of biomass type and biomass content to the pyrolysis and gasification result at low temperature. Mixing biomass with coal as the sample could promote gas production. Different kinds of biomass gave different improvement on gas production according to alkali metal content on its ash.

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References


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