Fundamental Study on Co-combustion and Co-gasification of Biomass with Low-grade Coal

Abstract

Recently, effective utilization of coals with high fixed carbon, sulfur, nitrogen, moisture and/or ash contents has been emphasized due to the economical considerations. Although some facilities to burn such coals have been developed, it is still hard to burn those coals completely. In some developing countries, on the other hand, emission control devices like de-NOx and de-SOx are not sufficiently employed and do not work effectively. Additionally, biomass resources have been focused as one of new energy resources since they are so-called carbon-neutral fuels. In considering the effective utilization of the coals with high content of fixed carbon, it is necessary to enhance the ignition and burnt-out characteristics. One of the candidate technologies to enhance those characteristics is generally recognized to be co-combustion and co-gasification technologies of coal with biomass. This is because the biomass has higher content of volatile matter than coal. The co-combustion and co-gasification technologies of biomass with coals have also been applied in several practical boilers to reduce CO_2 and other pollutants emission, fuel cost and so forth. Furthermore, the biomass may be able to control NOx emission since the biomass contains high volatile matter and evolves NH_3 as volatile-N species. However, fundamental emission characteristics of NO and N_2O for biomass and mixtures of biomass with coals during combustion have not been precisely elucidated yet. In order to solve those problems mentioned above, the main contents in this study are divided into the following chapters including the procedures and major conclusions of this work.

Chapter 1 gives brief introduction of biomass energy and low-grade coal utilization. Fundamental combustion and gasification technologies are summarized. The difficulties of utilization of low-grade are investigated. It is concluded that the co-combustion and co-gasification technology is one of the candidates to solve those problem as well as to reduce the emissions. Reviews of the previous studied relating to this work are also provided in this chapter.

Chapter 2 discusses the effect of cellulose and lignin content on pyrolysis and combustion characteristics for biomass. This study focuses on analysis of the main compositions for several types of biomasses. Fundamental pyrolysis and combustion characteristics for the biomass are analyzed, using a thermo-gravimetric (TG) analyzer. Pyrolysis and combustion experiments for the simulated biomass, which consists of mixture of cellulose with lignin chemical, are also conducted, to elucidate the effect of

the cellulose and lignin content in the biomass on the pyrolysis and combustion characteristics. The pyrolysis results for the actual biomass samples show good correlation samples on the tendency of decreasing fraction of combustibles with those for the simulated biomass. As the combustion results for the actual biomass samples differs from those for the simulated biomass samples, observation of morphological change before and after the reaction is conducted. As a result, the morphological change of biomass plays an important role for decreasing fraction of combustibles during combustion.

In Chapter 3, combustion experiments for biomass, coal and biomass-coal mixture are conducted, using an electrically heated drop tube furnace. In the combustion tests, the ignition behavior and combustion efficiency is focused, based on the results of gas compositions along the furnace axis. The results show that the biomass can enhance ignition characteristics of low-grade coal. Furthermore, the effect of co-combustion on size of ash particles at the exit is also obtained, sampling the reacting particles and observing them by a scanning electron microscope (SEM). Burning biomass with coal can shift the particle size from fine to coarse particles.

Chapter 4 discusses NO and N_2O behaviors during the co-combustion. As the results for NO and N_2O formation show unique phenomena, chemical kinetic simulations at constant temperature are also carried out, considering homogenous and heterogeneous elementary reactions relating to gaseous species evolving from coal and biomass and unburnt carbon, respectively. The results show that NO and N_2O formation during the co-combustion is influenced by the coal combustion, even if the input fuel-N under the co-combustion condition becomes smaller than that under the coal combustion condition. Results obtained by the kinetic simulation for NO and N_2O can agree well with the experimental results. The sensitivity analysis gives the main NO and N_2O formation/decomposition reaction schemes.

Chapter 5 studies co-gasification of biomass with coal in CO_2 atmosphere, using the electrically heated drop tube. The Hinoki sawdust biomass is selected for co-gasification because hinoki sawdust biomass gives higher gasification efficiency than others coals, since the biomass contains high volatile matter and easy evolves even in low temperature. Particle size also affects on increasing gasification efficiency as shown on the result of TH coal at 1273K higher than Hinoki sawdust biomass. Increasing the temperature also increases the conversion of synthesis gas. The results also show that adding biomass into the coal did not give an effect on enhance gasification efficiency, since the reaction is endothermic.

Chapter 6 summarizes the general conclusions obtained by this work. The results prove that the co-combustion and co-gasification technologies are suitable for utilization of low-grade coal with biomass as energy resources effectively as well as control of the pollutions. Based on our experimental results and literature studies we proposed the small power plant that suitable for distributed areas especially for developing countries such as Indonesia.