Combustion and thermal decomposition characteristics of brown coal and biomass

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Abstract

Among the fossil fuels, the brown coal is a great deal of resources. However, it is hardly used due to the high moisture content and low calorific value. It has both the weak points such as spontaneous combustion and high volatile content and the strong points such as the low-sulfur and low ash content. If we overcome these weak points, the using amount of brown coal would be increased. Also, it is well known that biomass is one of the important primary renewable energy sources because of carbon neutral energy. Furthermore, the utilization of biomass has been more and more concerned with the depletion of fossil fuel sources as well as the global warming issues. Combustion and thermal decomposition of biomass is one of the more promising techniques among all alternatives proposed for the production of energy from biomass.

In this study, combustion of brown coals and mushroom waste was done. Mass change of samples and emission of hydrocarbon components were measured. As the results, we obtained combustion rate constant. Also activation energy was calculated in char combustion step. Hydrocarbon components were more generated in low oxygen concentration than high. Emission amount of hydrocarbon components in mushroom waste was significantly increased comparing to brown coal.

**Key words**: Combustion, Thermal decomposition, Activation energy, Brown coal, Mushroom waste

1. Introduction

In recent years, fossil fuels are being exhausted due to increasing the demand for energy in developing/developed countries. The shortage of fossil fuels has been induced high price and unstable supply. The coal is a great deal of resources and a cheap price in comparing other fossil fuels, so that the demand will be steeply increased from now on. Among the coals, brown coal has the highest potential as one of future energy sources, and brown coal was mined and used extensively in several countries. The low rank coal, brown coal is about half of the coal resources, however, its production is approximately quarter of high rank coal. The reasons are that low rank coals have serious problems which are high moisture content, low calorific value and spontaneous combustion. If we overcome these weak points, the demand of brown coal would be increased, because it has strong points such as the low-sulfur and low ash content.\textsuperscript{1-4}

It is well known that biomass is one of the important primary and renewable energy sources because of carbon neutral energy. Furthermore, the
utilization of biomass has been more and more concerned with the depletion of fossil fuel sources as well as the global warming issues. Combustion and thermal decomposition of biomass is one of the more promising techniques among all alternatives proposed for the production of energy from biomass.

In this study, combustion experiments of the brown coal and mushroom waste as biomass have been done to characterize the combustion rate and the exhausted gas components. Effects of temperatures, oxygen concentration and particle size in combustion process are also discussed.

2. Experimental Procedure

The experiments were performed in an electrically heated furnace. The experimental apparatus is schematically shown in Fig.1. It is composed of an electrically heated furnace, temperature controllers, a digital balance, a flue gas analyzing system, and a flow control and gas mixing system. The time histories of brown coal mass and of concentration of SOx, NOx, CO, CO2 and O2 were continuously measured during the combustion process, respectively, by digital balance and the flue gas analyzing system. The combustion gas was preheated to a desired temperature by a packed bed of alumina ball located at the bottom of the furnace. The brown coal was placed in a basket, which was linked up with the upper digital balance, and was positioned in the center of the furnace axis. At the beginning of combustion, the electrical furnace that had the desired temperature was moved upward to rapidly heat the coal with avoiding the mass fluctuation. The influence of buoyancy on the indication of measured mass was neglected in these experimental conditions, about 2-5 cm/sec. In the experiments, the furnace temperature was set at a given temperature levels which ranged from 873K to 1073K. The flow rate of combustion gas was fixed at 10 L/min for the various combustion conditions in the atmosphere. During the combustion process, a part of flue gas was gathered and measured by gas chromatograph (ShimazuGC-8A). The oxygen concentration was controlled by varying the oxygen/nitrogen ratio. Oxygen concentration was changed between 0% and 21%. In this study, Wara brown coal and mushroom waste are used as a testing sample.

3. Results and discussion

3-1 Unburnt mass fraction change

At the 1073K, the time history of unburnt mass fraction of Wara brown coal is shown in Figure 2. It could be found that the Wara brown coal combustion process obviously has two stages. The first stage is volatile emission step which is a rapid
mass loss. The second stage is char combustion step which is slower mass loss. In the first stage which we call it volatile evolution/combustion step, the volatile evolves out from brown coal and burns around its surface. In the second stage which we call it char combustion step, the char combustion occurs slowly inside the brown coal and is controlled by oxygen diffusion. In the volatile evolution/combustion step, the unburnt mass fraction curve steeply decreases with similar tendency, despite the oxygen concentration changes from 5 to 21%. However, in char combustion step, the unburnt mass fraction curve is differently decreased with depending on the oxygen concentration. So in char combustion step, combustion rate is influenced by oxygen concentration. Fig. 3 showed combustion rate in char combustion step. X-axis is dimensionless time normalized by the complete combustion time. Combustion rate showed same tendencies at different furnace temperatures. Therefore, it is considered combustion rate is hardly influenced by furnace temperature in char combustion step. Fig. 4 showed combustion rate in char combustion step of mushroom waste. X-axis is time and Y-axis is logarithm unburnt fraction. The particle sizes were changed from 53 to 2400 micro meter. Combustion pattern was same tendencies at difference particle size. The mushroom waste's combustion rate constant was obtained from gradient of each particle diameter in char combustion step from Fig. 4. As a result, the small particle diameter's combustion rate constant is higher than large particle.

3.2 Activation Energy

In the char combustion step, if the semi-logarithm graph plotted about the unburnt mass fraction and time has linear relationship, this combustion step is the first-order reaction. The combustion rate constant, k, could be obtained from the slope in the first-order reaction. The activation energy could be taken from the Arrhenius plot of the combustion rate constant and temperature.

The char combustion step is the first-order reaction and we could get the activation energy by Arrhenius plot. Figure 5 shows Arrhenius plot of the 15% oxygen concentration for Wara brown coal and mushroom waste. The apparent activation
energies of each sample according to oxygen concentration in char combustion step are summarized in Table 1. We could get similar tendency in each sample. The apparent activation energy is increased with decreasing oxygen concentration.

3-3 Hydrocarbon component of flue gas to oxygen concentration

In this experiment, the hydrocarbon components of flue gas were measured by gas chromatograph in volatile emission step and char combustion step separately. In the case of volatile emission/combustion step, figure 6 shows the influence of oxygen concentration on the hydrocarbon component of flue gas for Wara brown coals. The main emission gases are CH₄ and C₂H₆. The amount of total emission of hydrocarbon was increased with decreasing oxygen concentration. It means that in low oxygen concentration, oxidation reaction was decreased. In the char combustion step, figure 7 shows the emission of hydrocarbon component of flue gas. Hydrocarbon in emission gas was little generated. Therefore, hydrocarbon is almost generated in volatile emission step. In the char combustion step, all the hydrocarbon components of flue gas have low influenced to oxygen concentration and reaction temperature.

4. Conclusions

The combustion and the thermal decomposition characteristics and properties of brown coal and biomass in different temperature, oxygen concentration, particle size effect have been discussed in detail by experiments.

The following conclusions could be derived in the combustion and thermal decomposition of brown coal and biomass.

1. In char combustion step, combustion rate is influenced by oxygen concentration. The combustion rate is hardly influenced by furnace temperature.
2. The apparent activation energy is increased with decreasing oxygen concentration.
3. The amount of total emission of hydrocarbon was increased with decreasing oxygen concentration in volatile emission step.
4. In char combustion step, hydrocarbon emission was little generated. Therefore, hydrocarbon gas is almost generated in volatile emission step.
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References


