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A gas-pressurized torrefaction method for biomass wastes

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ABSTRACT

Torrefaction is an efficient way for the biomass dewatering and upgrading before its thermal conversion and utilization. In this work, a gas-pressurized (GP) torrefaction method was proposed to torrefy the biomass wastes. The effect of gas pressure on biomass torrefaction was studied and the reaction mechanism was investigated in detail. The results indicated that the GP torrefied biomass had lower volatile matter content and higher carbon content than the torrefied biomass obtained by traditional method with carrier gas under atmospheric pressure (AP). The high heating values of GP torrefied rice straw and sawdust at 250 °C were as high as 17.9 MJ/Kg and 24.5 MJ/Kg, much higher than those of AP torrefied rice straw and sawdust which were13.6 MJ/Kg and 19.2 MJ/kg, respectively. The GP torrefaction at 250 °C removed as high as 77.88% and 66.68% of oxygen in rice straw and sawdust, respectively. Furthermore, it converted part of the volatile matter into fixed carbon through promoting aromatization reactions. The GP torrefied biomasses had richer pores and higher specific surface area than the AP torrefied biomasses. This can increase the reactivity for subsequent thermal conversion of the torrefied biomass. It was also found that the gas pressure significantly promoted the thermal decomposition of the hemicellulose and cellulose. The main difference of the reaction mechanism between the GP torrefaction and AP torrefaction was the secondary reactions between the volatiles and biomass. It was because the volatiles were not removed timely during GP torrefaction. Furthermore, the pressure was essential for effectively promoting the secondary reactions.

1. Introduction

On account of the increase of energy demand and the requirement of alternative to fossil fuels for sustainable environment, the role of renewable energy is increasingly prominent. Biomass is an important renewable energy source and accounts for approximately 10% of global energy consumption [1], because of its rich reserves, low sulfur and nitrogen contents, "carbon neutral" and so on [2]. It is believed that thermochemical conversions, such as combustion, gasification and pyrolysis, are feasible technologies for the biomass utilization as fuel. However, these technologies are challenging due to the inferior fuel properties of biomass, such as high water and oxygen contents, low calorific value, strong hygroscopicity, etc. [3]. Therefore, one of the key challenges for biomass utilization as fuel is to develop efficient pretreatment technology, which can make biomass compete with fossil fuels. Torrefaction is a promising pretreatment technology, which can improve the fuel properties of the biomass and therefore offers some solutions to above issues [4]. In general, the torrefaction is conducted in an inert atmosphere (such as N_2) at a relatively lower temperature range, typically from 200° C to 300° C. By torrefaction, the moisture contained in the biomass is substantially reduced, and the components of low molecular weight organic volatile and oxygen containing functional groups are reduced. As a result, hydrophobic solids with high fixed carbon content and high calorific value are produced [5]. The torrefied biomass has the properties like coal, and can be used to replace coal to a certain extent.

There have been many studies on biomass torrefaction [4,5]. The main target of the torrefaction is to remove oxygen and hence increase

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