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Release characteristics of alkali and alkaline earth metallic species during biomass pyrolysis and steam gasification process

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ABSTRACT

Investigating the release characteristics of alkali and alkaline earth metallic species (AAEMs) is of potential interest because of AAEM's possible useful service as catalysts in biomass thermal conversion. In this study, three kinds of typical Chinese biomass were selected to pyrolyse and their chars were subsequently steam gasified in a designed quartz fixed-bed reactor to investigate the release characteristics of alkali and alkaline earth metallic species (AAEMs). The results indicate that 53–76% of alkali metal and 27–40% of alkaline earth metal release in pyrolysis process, as well as 12–34% of alkali metal and 12–16% of alkaline earth metal evaporate in char gasification process, and temperature is not the only factor to impact AAEMs emission. The releasing characteristics of AAEMs during pyrolysis and char gasification process of three kinds of biomass were discussed in this paper.

1. Introduction

With the increasing depletion of fossil fuels and serious environmental problems (such as acid rain and green house effect et al.) caused by overuse of fossil fuels, researchers around the world are positively seeking new energy to substitute for fossil fuels. As a low-sulfur, low-nitrogen and carbon-neutral renewable clean energy, Biomass has great potential. And it is generally considered that gasification of biomass represents one of the most efficient ways of biomass utilization. In particular, steam gasification of biomass constitutes an attractive way to hydrogen renewable production for efficient power generation using gas turbine systems or fuel cells (Mustafa Balat and Mehmet Balat, 2009; Elif, 2011; Xiao et al., 2011).

However, biomass contains significant higher amounts of AAEMs (mainly K, Na, Ca and Mg) than other fuels such as coal, petroleum et al. Due to high AAEMs content in biomass, it's prone to volatilize and lead to serious problems such as slagging, agglomeration, deposition and heated side corrosion in the thermal utilization process (Gilbe et al., 2008; Knudsen et al., 2004; Ohman et al., 2005; Xiang and Li, 2012; Szemmelveisz et al., 2009). On the other side, the AAEMs contained in biomass also play catalytic role in thermal conversion process (Kajita et al., 2010; Keown et al., 2005; Eom et al., 2012; Zolin et al., 2001), and the released AAEMs may also act as catalysts for the steam reforming of volatiles in gas phase (Zolin et al., 2001).Thus a well understanding of AAEMs migration during thermal conversion process (especially gasification process) is highly significant for resourceful utilization of biomass.

Biomass gasification is constituted of two main processes: pyrolysis and char gasification. Numerous investigations had focused on release of AAEMs during biomass pyrolysis (Davidsson et al., 2002a; Jensen et al., 2000; Keown et al., 2005; Kowalski et al., 2007; Okuno et al., 2005; Olsson et al., 1997), but only a few comprehensive studies on release of AAEMs during biomass gasification (Hirohata et al., 2008; Keown et al., 2008) could be found. Moreover different experiment conditions as well as varied biomass samples lead to some conflict results. Keown et al., (2005) conducted pyrolysis of sugar cane bagasse and cane trash in a quartz fluidized-bed reactor, and found that less than 20% of AAEMs volatilized from biomass samples at a slow heating rate (~10 K/min) comparing to 80% of Na and K volatilized at fast heating rates (>1000 K/s). Okuno et al., (2005) studied the release of AAEMs during the pyrolysis of pulverized pine and sugarcane bagasse, and found heating the pine at 1000 °C/s up to 800 °C, 15–20% of each AAEMs was released during the tar evolution, afterward further isothermal heating caused nearly complete release of alkali metal within 150 s, while the release of alkaline earth metal terminated at levels of 20–40%. Jensen et al., (2000) studied release of K and Cl during straw pyrolysis using fixed-bed reactor, and found no significant potassium release below 700 °C; above 700 °C it increased progressively until about 25% potassium release at 1050 °C.

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