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Syngas Production via CO_2 Enhanced Gasification of Biomass Fuels

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Abstract

This paper presents experimental results of decomposition tests for biomass to syngas conversion. The gasification process was found to yield improved char conversion and higher levels of H_2 and CO for various CO_2 recycle ratios. Carbon monoxide production from steam gasification was enhanced by increasing the CO_2 input flow rates. The evolution of H_2 gas only became significant at high gasification temperatures above 650°C for the wood and 500°C for the herbaceous and nonwood biomass samples studied. Using thermogravimetric analysis (TGA), gas chromatography (GC), atomic absorption spectroscopy (AAS), calorimetry, and the scanning electron microscope with energy dispersive X-ray analysis (SEM/EDX) the nature of the biomass composition and ash residue, and the mass decay of biomass sources including various woods and grasses were studied. These were poplar, red oak, sugar maple, white pine, spruce, Douglas fir, pine needles, maple bark, alfalfa, cordgrass, and American beachgrass. Hydrogen, carbon monoxide and methane gas evolution as a function of temperature was also quantified. The woods and grasses had similar TGA curves with a third level mass step during high temperature steam gasification showing completed mass loss by 900–1,000°C. Two distinct regimes of mass decay, representing pyrolysis and gasification and char burnout, were found to correlate well with the two corresponding gas evolution regimes for CO and H_2. An SEM/EDX analysis also showed high levels of potassium (K), magnesium (Mg), and phosphorus (P) in the ash residue. The mineral content of the biomass sources, and particularly the high alkaline content of the grassy feedstocks used in the present study, were held responsible for the corrosion of the quartz TGA furnace. This composition necessitates the careful selection and possible need for preprocessing of biomass fuels to minimize corrosion of the operating equipment. Gasification prior to high-temperature combustion enables the removal of the corrosive ash elements such as potassium and chlorine that would otherwise be problematic.

Key words: syngas production; CO_2 enhanced gasification of biomass fuels

Introduction

Biomass fuels, that constitute one group of the more promising renewable energy sources available, can alleviate the immediate need to meet increasing energy demands in an environmentally responsible way. In the United States, renewable energy accounts for only a few percent of the total energy consumption with one-third of the renewable sources attributable to woods, grasses, and agricultural and forestry wastes and residues. Biomass feedstocks have the potential to produce many of the chemicals currently derived from fossil fuel sources. Woody biomass includes trees, shrubs and bushes. Nonwoody biomass includes grasses, straw, stems, roots, leaves, water plants, starchy fruits such as bananas and plantains, fibrous seed plants such as cotton, fleshy root plants such as cassava, and energy crops such as sugarcane. Thermal treatment of hydrocarbon fuels can involve thermal cracking (pyrolysis), decomposition into volatile species (gasification) or burning in the presence of oxygen (combustion). The thermal processing of plant biomass, whether by pyrolysis, gasification, or combustion, involves returning to the environment the carbon that has been removed during the growth of the tree or grass. For this reason biomass is considered a carbon neutral energy source. However, the complex molecular structure that makes up the biomass fuels

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