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Short Communication

TG–FTIR study on co-pyrolysis of municipal solid waste with biomass

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ABSTRACT

Co-pyrolysis of cotton stalk, a representative agricultural biomass in China, mixed with municipal solid waste (MSW) with high ash content and low calorific value was carried out using a thermogravimetric analyzer (TGA) coupled with a Fourier transform infrared (FTIR) spectrometer in Ar atmosphere. Pyrolysis characteristic and pollutant emission performance from MSW and stalk blends at different mass proportions were studied. The results show that as the mass proportion of stalk added increases, the total weight loss of the blend during pyrolysis increases. The addition of stalk has substantial effects on the N-selectivity to HCN, NH_3 and HNCO. In the presence of stalk, lower concentrations of HCl are detected.

1. Introduction

There is currently a considerable interest in the efficient use of MSW as energy source. Incineration has gradually taken as major disposal measures for recovering energy from MSW (Lima et al., 2008; Liang et al., 2008). However, incineration of MSW brings serious environmental problems, such as the emissions of NO_X, N_2O, SO_2, HCl and dioxins (Cheung et al., 2007; Zhu et al., 2008; Persson et al., 2007). Therefore, it is necessary to explore cleaner techniques for MSW recycling.

The components and heating values of MSW vary largely at different seasons and districts in China. There are high contents of moisture and ash and lower heating values in MSW in northern part of China during winter. It is difficult to ignite and burn out alone, and the efficiency of MSW power generation is extremely low.

Biomass is an effective substitute for fossil fuels and has a substantial impact on CO_2 reduction (Yan et al., 2005; Worasuwannarak et al., 2007).Agricultural straw wastes are abundant in China. Its annual output is 600 million tons in 2003, but over 120 million tons of stalks were discarded on field or directly set on fire, which is not only a waste of resources but also causes environmental pollution.

Co-combustion/gasification of agricultural residues with MSW is one of the novel areas in the global cleaner energy strategy (Yang et al., 2004). It can reduce pollutant emitted from MSW incineration and also eliminate waste of biomass resources and environmental pollution. Unfortunately, there is still a lack of detailed theoretical study on co-combustion/pyrolysis of biomass with MSW.

The objective of this research was to use TG–FTIR analysis to investigate the possibility of co-firing/gasifying MSW-stalks blends. The pyrolysis characteristics and pollutant (HCl, NO_X and N_2O precursors) emission performances continuously from MSW and MSW-stalk blends were studied.

2. Methodology

2.1. Materials

The preparation of experimental sample was based on the representative components of MSW chosen from Jinan, Shandong, China. The samples were mixed artificially according to the component proportion. The simulated MSW sample was a mixture of five main components, containing (mass composition) 36% kitchen residue, 6% paper, 5% PVC, 9% sawdust and 44% coal ash. The ash content in the MSW was up to about 49%, and the heating value was only 2.94 MJ kg^{-1}. All the typical materials were cut into 0.5 mm (mean particle size) in diameter and mixed before experiment to ensure a representative sample was used. Cotton stalk, a representative agricultural biomass in China was used as the biomass sample. The contents of volatile matter, fixed carbon and ash are up to 75.66% (wt.%, dry ash free basis), 24.34% and 1.78%, respectively.

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Sulfur and nitrogen content is 0.13% and 0.30%, respectively. The stalk sample was ground into particles less than 0.1 mm in diameter.

2.2. Apparatus and product analysis

Co-pyrolysis of MSW with stalk was performed with a TG analyzer (TGA) in argon atmosphere. Experiments were carried out from room temperature to 900 °C at 40 °C min^{-1}. The total mass of each mixture was around 50 mg. Evolved gases from TGA were connected to and detected on-line by a FTIR spectrometer. The HCl IR spectrum is characterized by an intense vibrational band located at 2798 cm^{-1}. The concentration of each gaseous product was determined based on the integral value of the release curves under specific IR absorptions. Detailed information about the TGA–FTIR apparatus and product analysis method can be referred to reference (Ren et al., 2008).

3. Results and discussion

3.1. Co-pyrolysis characteristics

As the stalk share increases, the final weight loss of MSW and MSW-stalk blends is 32.39%, 37.02%, 41.62%, 49.05%, 51.22% and 57.90%, respectively. The final weight loss of stalk is 77.49%. For blends, the weight loss curves lie between MSW and cotton stalk. The lowest final weight loss of MSW is related to the high ash content in MSW.

3.2. Nitrogen species release characteristics

It is well known that ammonia (NH_3), hydrogen cyanide (HCN), isocyanic acid (HNCO) and organics are the precursors of nitrogen oxides (NO_X and N_2O). HNCO is believed to be a precursor to N_2O (Hansson et al., 2004; Kleemann et al., 2000). So the formation of HNCO during fuel pyrolysis was emphatically analyzed in this study.

Fig. 1 shows the formation curves of NO_X precursors for MSW, cotton stalk and their blends. For MSW, the release curves of HCN and NH_3 have one peak, while that of HNCO has two peaks at 333 °C and 505 °C, respectively. Compared with MSW, each release curve of the three NO_X precursors from cotton stalk and the blends has only one peak. Furthermore, nitrogen species release faster for cotton stalk than those for MSW during pyrolysis, which is in accordance with the TG results.

It can be seen from Fig. 1, as the mass proportion of stalk added increases, initial release temperatures of HCN, NH_3 and HNCO become lower. The emission of HCN or NH_3 as well as HNCO at lower temperature from the mixtures is higher than that of MSW, but in higher temperature region (>500 °C), the HNCO emission from the mixtures decreases and is lower than that from MSW.

The yields of the nitrogen species from MSW, stalk and their blends were compared and showed in Table 1. It is clear that the variation in the nitrogen species formation is affected by added stalk.

As Table 1 shows, with the increase in the mass proportion of stalk added, the yields of HNCO change a little, and the yields of HCN and NH_3, especially NH_3 have an obviously increasing trend. The addition of stalk promotes the total yields of nitrogen species.

The share of nitrogen species of the samples with and without stalk during pyrolysis can be obtained from Table 1. It indicates that HCN and HNCO are the main N-compounds for MSW, counting for about 40% and 37% of the total yields of NO_X precursors, respectively. However, NH_3 and HCN are the main N-compounds for cotton stalk, counting for about 46% and 39% of the total yields of NO_X precursors, respectively. As the mass proportion of stalk increases, the share of HCN or NH_3 increases, while that of HNCO decreases. The mass fraction of HCN increases slowly. The mass fraction of NH_3 increases obviously as the mass proportion of stalk increases to 30%, then keeps constant with the further increase in the mass proportion of stalk. However, the mass fraction of HNCO decreases significantly as the mass proportion of stalk increases to 30%, then keeps constant. HCN and NH_3 become the main N-compounds for the mixtures, counting for 43% and 39% when the mass proportion of stalk is 50%.

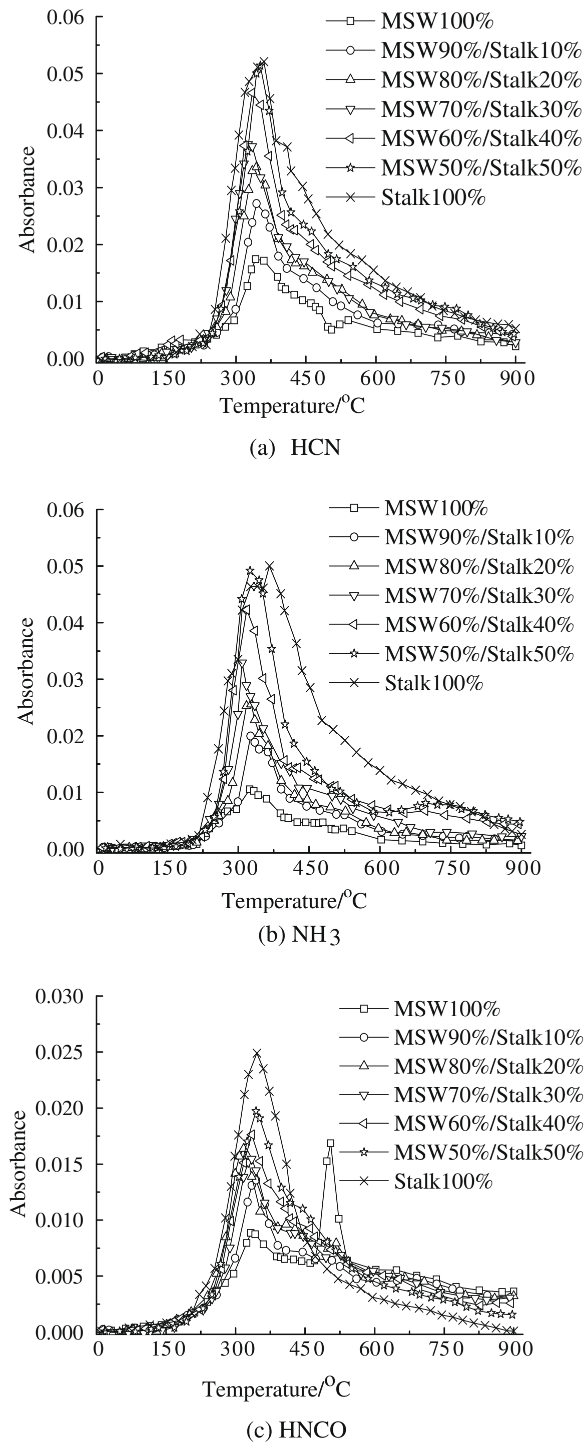

Fig. 1. Release curves of nitrogen species from pyrolysis of MSW, cotton stalk and their blends obtained from TG–FTIR analysis.