Synergy of plastic-paper co-pyrolysis in MSW: Thermal behavior and product characteristics

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1. Introduction

With the swift urbanization and population surge, municipal solid waste (MSW) generation has escalated. Its complex composition, including waste plastics and paper, poses treatment challenges. Plastics and paper make up 41.73% and 27.94% of MSW in China respectively [1]. They are rich in organic compounds and can be energy resources. Incineration, though widely used, has high pollution [2]. Gasification, converting MSW into valuable products, is a better choice [3]. Given MSWs varied composition and size, fixed -bed reactors are suitable [4]. The updraft fixed-bed reactor is especially good for gasification. Studying plastic-paper co-pyrolysis in such a reactor is vital.

Plastics like PVC, PE, PP, PS, and PET account for 70% of waste plastics in MSW, as per Plastics Europe [5]. With a low recycling rate, they are common in MSW. Their pyrolysis temperatures differ. Paper, mainly cellulose, has a thermal decomposition range. During pyrolysis, theres a synergistic effect between plastics and paper [6]. Current research on co-pyrolysis and gasification mainly looks at plastic type, temperature, and blending ratio [7]. But accurate sorting of waste plastics is hard, and the impact of plastic melting on co-pyrolysis needs more study. This work examines the pyrolysis behavior and synergistic effects of plastics and paper in MSW.

2. Material and methods

PVC, PE, PP, PS, and PET (from Aladdin Co.) were mixed in the proportion of 18:38:27:8:9. Waste printing paper was shredded. The plastic-to-paper blend was prepared based on the ratio of 3:2. The effect of temperature (300-700 °C) on thermal behavior was investigated via a fixed bed reactor during co-pyrolysis. The carbon skeleton structural parameters of pyrolytic char were obtained by the nuclear magnetic resonance. The impact of plastic melting on the co-pyrolysis process was clarified utilizing a high-temperature hot-stage microscope (HTSM).

3. Results and discussion

As temperature rose, pyrolytic char yields dropped from 70.7% to 17.1%, with minor changes beyond 500 °C (Fig. 1.). In co-pyrolysis, char yield was 4.00%-12.7% higher than calculated, peaking at 400 °C. It was mainly due to plastic melting encapsulating paper and interactions between volatiles and char. At 400 °C, 13C NMR showed co-pyrolytic char had more aliphatic carbon atoms, linked to plastic melting hindering alkene cleavage. The interaction of plastic volatiles with paper char also raised certain carbon atom intensities. Additionally, the specific surface area and pore volume of pyrolytic char were reduced, partly due to plastic melting and volatiles clogging pores.

HTSM was used to study the in-situ co-pyrolysis of plastic and cellulose (Fig. 2.). Cellulose decomposition began at 300 °C. The plastics softened and turned into liquid droplets at different temperatures, then enveloped cellulose particles. This encapsulation by molten plastic caused pyrolytic gases from cellulose to accumulate, increasing pressure and forming gas bubbles, thus inhibiting cellulose thermal decomposition. Different plastics showed varied melting and encapsulation behaviors. HTSM findings explained the significant char yield increase at 400 °C. Though plastic melting was prominent at 300 °C, it had little effect on char yield due to low volatiles release. At 400 °C, cellulose volatiles release was enhanced, but plastic thermal weight loss was low except for PVC, showing strong encapsulation. Beyond 500 °C, volatile release from both paper and plastics increased, weakening the plastic encapsulation effect and reducing char yield in co-pyrolysis.

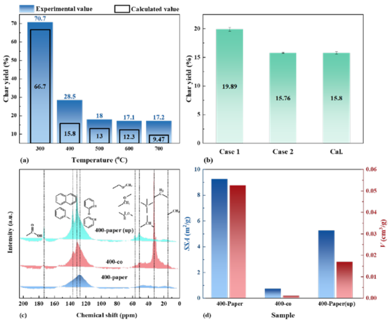

Fig. 1. Pyrolytic char yields (a-b), 13C NMR spectra (c), and pore structure parameters (d).

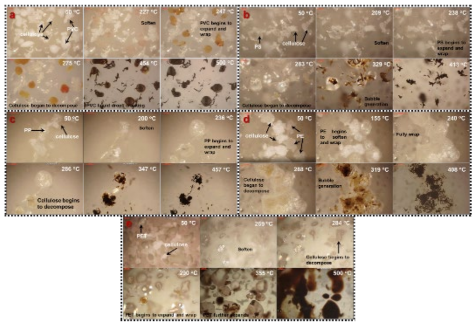

Fig. 2. Photographs of the process of cellulose and different plastics; (a) PVC, (b) PS, (c) PP, (d) PE, and (e) PET.

4. Conclusion

The co-pyrolysis behavior of plastic and paper, typical components in MSW, was investigated. Pyrolytic char yields were increased by 4.0%-12.7% within 300-700 °C, with the highest increase observed at 400 °C. This improvement was attributed to the melting effect of plastics and the interactions between paper char and plastics volatiles, contributing 8.6% and 4.1%, respectively. The melting mainly increased the aliphatic carbon atom content, while the interactions elevated the levels of oxy-aliphatic and aromatic carbon atoms. Compared to PS, PP, and PE, PVC and PET exhibited a broader temperature range (above 500 °C) for cellulose encapsulation.

Acknowledgements

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