Investigation of pyrolysis characteristics and gasification activity of municipal solid waste briquettes: A comparative study

Xueli Chen[a,b*], Zichao Hu[a,b]

[a]Engineering Research Center of Resource Utilization of Carbon-containing Waste with Carbon Neutrality, Ministry of Education, Shanghai 200237, PR. China

[b] Shanghai Engineering Research Center of Coal Gasification, East China University of Science and Technology, Shanghai 200237, PR. China

Keywords: Municipal solid waste; Briquetting; Pyrolysis characteristics; Gasification activity; Fixed bed

Presenting author email: cxl@ecust.edu.cn

1. Introduction

As the largest global municipal solid waste (MSW) producer, China registered a transportation amount of 244.47 million tons in 2022, leading to severe environmental and social issues. Therefore, the development of efficient and economical methods for MSW treatment is imperative. Gasification is considered an efficient and promising method for MSW treatment (Niu et al., 2014), with pyrolysis playing an essential role. The pyrolytic gas, tar, and char can be utilized in power generation, hydrogen production, and the chemical industry (Ding et al., 2021; Rego et al., 2022). Nevertheless, the complex composition, loose structure, and low energy density of MSW pose challenges for thermal conversion. Briquetting can significantly improve the volume energy density of MSW, providing a possibility for large-scale treatment of MSW. However, the study of MSW pyrolysis has predominantly focused on powdered samples (Bin et al., 2022; Song et al., 2020). Compared to the powdered MSW, the heat and mass transfer effects of MSW briquettes are more pronounced, resulting in a spatial distribution of temperature and pyrolysis reaction within particles (Meng et al., 2019; Wang et al., 2020). This not only alters the characteristics of the pyrolysis products but also affects the subsequent gasification process. Therefore, it is necessary to study the product properties of MSW briquettes pyrolysis and its influence on the gasification process.

2. Material and methods

The MSW was collected from a waste treatment plant in Yang Zhou, China. The raw MSW was crushed. Then, the MSW briquettes, with a diameter of 20 mm, were prepared using the power briquetting device. The pyrolysis of MSW powder (MSW-P) and MSW briquettes (MSW-B) was conducted on a fixed-bed reactor. Particularly, the pyrolytic char of MSW-B was characterized and divided into internal and external parts. Based on Thermogravimetry analysis, the gasification activity of the pyrolytic char was employed to examine.

3. Results and discussion

After briquetting, pyrolytic char yields were increased. At temperatures < 600 ºC, The gas yields of MSW-B were lower than those of MSW-P, while at 700 ºC and 800 ºC increased by 3.6% and 3.02%, respectively. Specifically, the yields of H_2, CH_4, and CO of MSW-B were increased at 700-800 ºC, while yields of C_2H_4 and C_2H_6 were decreased. Moreover, the MAHs content was lower, but the PAHs content showed an opposite trend. It is indicated that the increase in gas yield at 700-800 ºC was mainly due to the secondary reaction of volatiles.

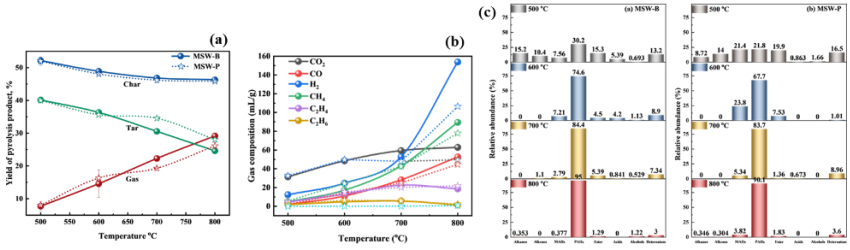

Fig. 1. (a) Pyrolysis product distribution, (b) pyrolytic gas composition, and (c) pyrolytic tar composition

The I_G/I_{AII} values for MSW-B were higher than those of MSW-P (Fig. 2(a)), stating a more ordered carbon structure in the briquette char. This difference decreased with temperature. However, the value of I_G/I_{AII} of internal and external char was relatively small. For the pore structure, the surface specific area of the briquette char was

improved, particularly the internal char. Owing to the change of carbon structures and pore structure, the gasification reaction activity of External char (128.91 kJ mol^{-1}) was lower than Internal char (128.91 kJ mol^{-1}). Since the carbon structures of the briquette char were similar, these differences were primarily attributed to the pore structure. However, the *E* of the char of MSW-B and MSW-P was relatively similar. In summary, the increased heat and mass transfer resistance of MSW briquettes led to a slower heating rate of pellets and reduced volatile release, resulting in the spatial distribution of pyrolysis char properties and altering the gasification path.

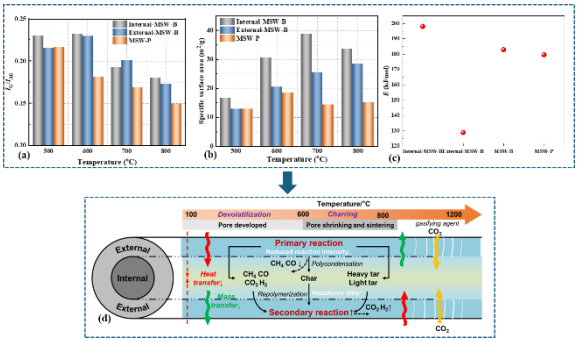

Fig. 2. Potential mechanism for pyrolysis and gasification for MSW briquettes

4. Conclusion

In this study, the pyrolysis characteristics and gasification activity of MSW briquettes were studied. After briquetting, the pyrolytic gas yield at 500-600 °C was decreased, while increasing at 700-800 °C. The pyrolytic char yield was increased. Moreover, the order degree of carbon structure and the *SSA* of pyrolytic char were enhanced, especially internal char. The difference in gasification activity between external char (128.91 kJ/mol) and internal char (128.91 kJ/mol) was mainly attributed to its pore structure. However, the *E* of the briquette and powdered char were close.

Acknowledgments

This work was supported by the Social Development Science and Technology Tackling Project of 2020 "Scientific and Innovative Action Plan of Shanghai" (No. 20dz1203300), the National Natural Science Foundation of China (No. 22108081).

Reference

[1] Bin, Y., Yu, Z., Li, M., Huang, Z., Zhan, J., Liao, Y., Zheng, A., Ma, X., 2022. Ex-situ catalytic co-pyrolysis of sawdust and municipal solid waste based on multilamellar MFI nanosheets to obtain hydrocarbon-rich bio-oil. J. Anal. Appl. Pyrol. 167, 105673.

[2] Ding, G., He, B., Yao, H., Kuang, Y., Song, J., Su, L., 2021. Synergistic effect, kinetic and thermodynamics parameters analyses of co-gasification of municipal solid waste and bituminous coal with CO_2. Waste Manag. 119, 342-355.

[3] Meng, D., Wang, T., Xu, J., Chen, X., 2019. A numerical study on the pyrolysis of large coal particles: Heat transfer and volatile evolution. Fuel 254, 115668.

[4] Niu, M., Huang, Y., Jin, B., Wang, X., 2014. Oxygen Gasification of Municipal Solid Waste in a Fixed-bed Gasifier. Chinese J. Chem. Eng. 22, 1021-1026.

[5] Rego, F., Xiang, H., Yang, Y., Ordovás, J.L., Chong, K., Wang, J., Bridgwater, A., 2022. Investigation of the role of feedstock properties and process conditions on the slow pyrolysis of biomass in a continuous auger reactor. J. Anal. Appl. Pyrol. 161, 105378.

[6] Song, Q., Zhao, H., Jia, J., Yang, L., Lv, W., Bao, J., Shu, X., Gu, Q., Zhang, P., 2020. Pyrolysis of municipal solid waste with iron-based additives: A study on the kinetic, product distribution and catalytic mechanisms. J. Clean. Prod. 258, 120682.

[7] Wang, T., Meng, D., Zhu, J., Chen, X., 2020. Effects of pelletizing conditions on the structure of rice straw-pellet pyrolysis char. Fuel 264, 116909.