Effect of Hydrothermal Treatment on Co-Combustion Interactions and Mechanism of Oil Sludge Char with Biomass

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INTRODUCTION

Oil sludge is classified as a hazardous waste in many countries due to the high concentration of petroleum hydrocarbons. Pyrolysis is a promising method for converting oil sludge into light oil and flammable gas. However, char (OSC) thus furnished still poses an environmental risk due to residual oil components (Cheng et al., 2019). Combustion is an efficient treatment method for char disposal and resource recycling. While the high ash content in OSC conversely inhibits its combustion performance, and it also makes combustion an energy-intensive process. Regarding simplicity and effectiveness, co-combustion is an optional choice to remedy the low efficiency of OSC combustion. Previous studies have proved that biomass can be a viable alternative to fossil fuels for energy harvesting (Sahu et al., 2014). Nevertheless, the inherent alkali metals in biomass results in ash-related problems such as slagging, fouling, and corrosion. Accordingly, hydrothermal treatment (HTT) has been regarded as a promising way to upgrade biomass, through which alkali metals are partially removed, and homogeneity is ameliorated therefore improving the combustion performance (Tekin et al., 2014).

Research on the co-combustion between OSC and hydrochar has not received much attention; however, its study is vital in optimizing oil sludge treatment. This work reports a comparative study of the co-combustion mechanisms of OSC with biomass and hydrochar.

MATERIALS AND METHODS

Sample preparing

OSC samples were obtained from pyrolysis of oil sludge at 450°C in a vertical tube furnace. Cherry blossom wood was used as the raw biomass samples (RW). Hydrochars (HW) were obtained from HTT experiments, which were conducted in a stainless steel reactor, and the reaction temperature and holding time were 220°C and 60 min, respectively. The blends of OSC and RW were tagged MR28, MR55 and MR82 with the proportion of OSC was 20%, 50%, and 80%, respectively. OSC and HW were blended using the same method, tagging as MH28, MH55 and MH82, respectively.

Experimental methods

Combustion experiments were performed in a differential thermogravimetric analyzer. Around 10 mg samples were heated from ambient temperature to 1000°C under air atmosphere at a flow rate of 60 ml/min and heating rates (5, 10, 40, and 50°C/min).

RESULTS AND DISCUSSION

Combustion behavior of the blends

Figure 1 shows the combustion characteristics of different blends at a heating rate of 40°C/min. As shown in Figure 1 (a-2) and (b-2), in stage 1, the maximum weight loss rate for RW and HW both decreased with the addition of OSC. Similarly, in stage 2, the OSC addition caused the decrease of peak weight loss rate. Whereas, the combustion stage and burnout temperature exhibited an opposite trend for two blends, which indicated there existed different interactions after blending.

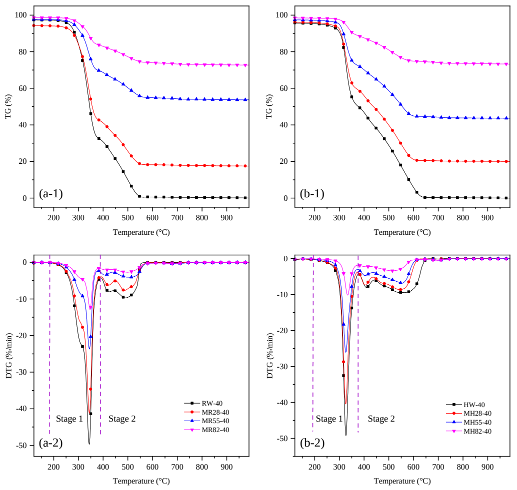

Figure 1 Combustion characteristics of the blends

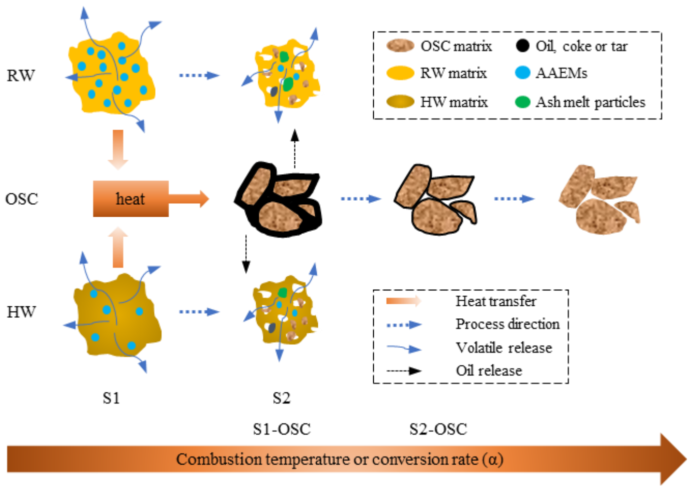

Figure 2 Proposed mechanism diagram during combustion of the blends

Proposed mechanism during co-combustion of the blends

As shown in Figure 2, during co-combustion, the alkali metals in RW reacted with the ash in OSC, forming melt substances which hindered the combustion reaction. After HTT, less alkali metals and a rough surface structure were more conducive for the diffusion of gas and oxygen penetration, thereby improving the combustion efficiency.

CONCLUSION

HTT could reduce the slagging and fouling problems during co-combustion of OSC and biomass. Conversely, OSC addition could narrow the combustion stage of HW. Overall, the blending of biomass could effectively improve the combustion performance of OSC, and HTT could further enhance the positive interaction in the co-combustion process.

REFERENCES

Cheng, S., Zhang, H., Chang. F., et al., Combustion behavior and thermochemical treatment scheme analysis of oil sludges and oil sludge semicokes, Energy, 167, 575-587, 2019.

Sahu, S, G., Chakraborty, N., Sarkar, P., Coal–biomass co-combustion: An overview, Renewable and Sustainable Energy Reviews, 39, 575-586, 2014.

Tekin, K., Karagöz, S., Bektaş, S., A review of hydrothermal biomass processing. Renewable and sustainable Energy reviews, 40, 673-687, 2014.