Investigating of waste plastic co-pyrolysis with char by ANFIS coupled with ant colony algorithm

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Abstract: In this study, the waste plastic (WP) co-pyrolysis with char was investigated. The thermogravimetric (TG) experiments of WP, char and WP/char mixture materials with different WP mass fractions were conducted at 30 °C/min from room temperature to 700 °C, under nitrogen atmosphere. According to the experimental data, there were differences between the experimental and linear calculated results of WP/char mixture materials. For the purpose of determining the optimal operating conditions for obtaining the maximum conversion rate and pyrolysis rate enhancements, the adaptive neural fuzzy inference system (ANFIS) was adopted to establish the arithmetic expressions between the independent variables (namely the WP mass fraction and the temperature) and the dependent variables (conversion rate and pyrolysis rate enhancements). Furthermore, the ant colony algorithm (ACA) was utilized to determine the optimal temperatures and WP mass fractions.

Introduction: Waste plastic (WP) is a considerable component of the municipal solid waste worldwide [1]. Besides, the char is regarded as proper material which could be co-pyrolyzed with the WP to produce sustainable fuels [2]. The co-pyrolysis effect is non-linear for both conversion rate and pyrolysis rate compared to the separate feedstocks' pyrolysis results [3]. However, due to those non-linear effects, it is difficult to determine the optimal operating conditions for the co-pyrolysis enhancement with conventional methods. Therefore, this study intends to investigate the optimal conversion rate and pyrolysis rate enhancements of the WP co-pyrolysis with char by the neural fuzzy model and the optimization algorithm.

Material and methods: The WP was provided by the Luk-Plast Ind. (ES-Brazil). The char was bought from a commercial company, and it was used as received. The TG experiments of WP, char, and WP/char mixture materials with 25 and 75 wt% WP mass fractions were conducted at 30 ℃/min from room temperature to 700 ℃, respectively. The adaptive neural fuzzy inference system (ANFIS) is a widely used neural fuzzy model, which could establish a mathematical expression between the multiple independent variables and induced variables [4]. Therefore, the ANFIS was adopted to establish the arithmetic expressions of the WP mass fraction, the temperature, the conversion rate and the pyrolysis rate enhancements. Additionally, ACA, proposed by Marco Dorigo et al [5], was used to determine the optimal operating conditions, i.e. the WP mass fraction and the temperature.

Results and discussion

Figure 1 illustrated the experimental mass fractions and pyrolysis rates of the WP, char, and WP/char mixture materials with 25 and 75 wt% WP mass fractions. As shown in Figure 1a, the char mass fraction decreased gradually when the temperature increased. The char underwent a slow decomposition process compared to the WP and the WP/char mixture materials. The pyrolysis processes of the WP and the WP/char mixture materials were conducted in the temperature range of about 400-550 ℃. Besides, the mass fraction curve shifted laterally to a high temperature when the WP mass fraction increased from 25 to 75 wt%. Regarding the pyrolysis rate as described in Figure 1b, the WP/char mixture materials with 25 and 75 wt% WP mass fractions had the same trends as the WP. However, the maximum pyrolysis rate decreased when the WP mass fraction decreased. For instance, the maximum pyrolysis rates were 96.35, 88.36 and 34.74 wt%/min when the WP mass fractions were 100, 75 and 25 wt%, respectively. Additionally, the maximum pyrolysis rate of char was merely 0.77 wt%/min.

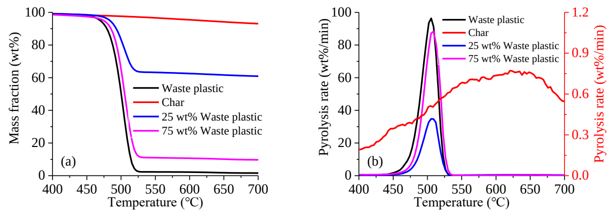

Figure 1. Experimental mass fractions and pyrolysis rates of the WP, char and WP/char mixture materials.

Figure 2a and 2b demonstrated the experimental and the linear calculated conversion rates and the pyrolysis rates of the WP/char mixture materials with 25 and 75 wt% WP mass fractions, respectively. As depicted in Figure 2a, the experimental conversion rates were higher than the linear calculated results at the end of the pyrolytic processes. For instance, the linear calculated and experimental conversion rates were 29.79 and 39.09 wt%, and 75.53 and 90.31 wt% at 700 ℃ with 25 and 75 wt% WP mass fractions, respectively. As shown in Figure 2b, the maximum experimental pyrolysis rates were distinctly higher than the linear calculated ones. The maximum linear calculated and experimental pyrolysis rates were 24.47 and 34.74 wt%/min, and 72.39 and 88.36 wt%/min when the WP mass fractions were 25 and 75 wt%. Additionally, Figure 2c and 2d described the conversion rate and the pyrolysis rate differences between the experimental and the linear calculated results, respectively. The differences indicated that the char could both enhance and inhibit the WP pyrolysis conversion rate and pyrolysis rate in different temperature ranges.

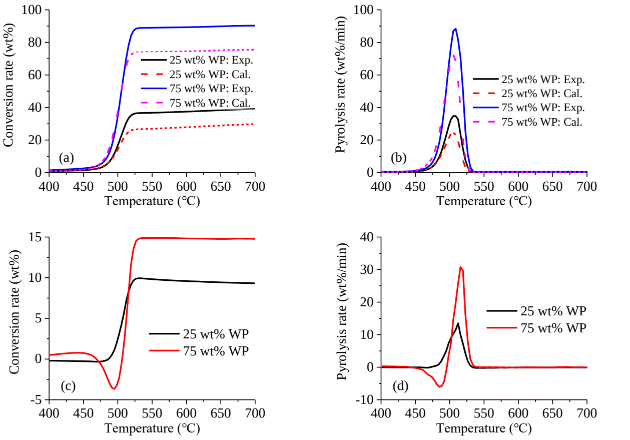

Figure 2. The WP co-pyrolysis effects with char.

Figure 3 depicted the optimal co-pyrolysis conversion rate and the pyrolysis rate predicted by ANFIS coupled with ACA. The ANFIS had established the arithmetic expressions between the independent variables (the WP mass fraction and the temperature) and the dependent variables (the co-pyrolysis effects of the conversion rate and the pyrolysis rate). Hence, the co-pyrolysis effects on the conversion rate and the pyrolysis rate could be determined by the WP mass fraction and the temperature. As demonstrated in Figure 3, the ANFIS predicted co-pyrolysis conversion rate and the pyrolysis rate had the same trends with the experimental ones in Figure 2. It revealed the accuracy of the ANFIS predicted results to a certain extent. Moreover, as shown in Figure 3a, the ACA determined optimal co-pyrolysis effect of the conversion rate was 15.02 wt% at 538.61 ℃ with the WP mass fraction of 75.00 wt%. Subsequently, as described in Figure 3b, the optimal co-pyrolysis effect of the pyrolysis rate determined by the ACA was 31.66 wt%/min at 516.89 ℃ with the WP mass fraction of 75.00 wt%.

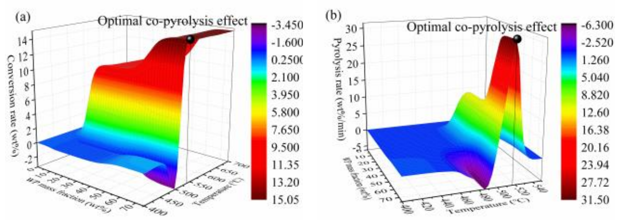

Figure 3. The optimal co-pyrolysis conversion rate and pyrolysis rate predicted by ANFIS coupled with ACA.

Conclusion: This study investigated the WP co-pyrolysis with char. The TG experiments of WP, char and WP/char mixture materials with 25 and 75 wt% WP mass fractions were conducted at 30 °C/min from room temperature to 700 ℃. It revealed that there were differences between the linear calculated and the experimental results of the WP/char mixture materials pyrolysis. Moreover, the differences proved that the conversion rate and the pyrolysis rate could be enhanced in specific temperature ranges with different WP mass fractions. Therefore, the ANFIS coupled with ACA was adopted to determine the optimal operating conditions for obtaining the optimal enhancements of the conversion rate and the pyrolysis rate. Consequently, the optimal enhancement of the conversion rate was 15.02 wt% at 538.61 ℃ with the WP mass fraction of 75.00 wt%. Ulteriorly, the optimal enhancement of the pyrolysis rate was 31.66 wt%/min at 516.89 ℃ with the WP mass fraction of 75.00 wt%.

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