

PYROLYTIC LIQUID FUEL FROM RMSW USING LONG CATALYZER DOWNSTREAM IN STAGE PYROLYSIS

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Abstract

The thermal degradation of Real Municipal Solid Waste (RMSW) at 500 °C has led to meager mass yields of liquid fuel. Therefore, this study examines the possibility of increasing the mass yield using Long Catalyser Downstream (LCD) equipped with top and bottom outlet in stage pyrolysis. Two natural catalysts, zeolite, and kaolin were activated at 500 °C for 2 hours and used in this experiment. Also, LCD temperature was varied between 200 °C and 300 °C while the pyrolyzer temperature was held at 500 °C. The experimental results showed that there was a significant increase in the mass yield of liquid fuels compared to pyrolysis with and without catalysts. The presence of LCD facilitates secondary cracking and produces short hydrocarbons ranging from RMSW feedstock. Natural zeolite catalysts have better productivity behavior compared to natural kaolin. It also leads to higher mass yields in liquid fuels.

1. Introduction

Since there are a lot of worries over the future energy crisis and the significant increase in the growth of municipal solid waste, converting MSW into liquid fuel is the best solution to be considered. Pyrolysis is a well-established method of thermal degradation that converts waste into energy. This method is considered flexible since it is very simple and produces three types of energy products simultaneously, including liquid, solid, and gas fuels [1]. Syngas is a permanent gas, such as methane and hydrogen, while liquid fuel is a product obtained from the condensation of volatile products [2]. These two can be used as gas engine fuels that converts into electricity, which is more efficient compared to the direct combustion process [3] [4]. It also has a very low environmental impact [5,6]. The percentage of the pyrolysis products in solid, liquid, and gaseous depends on the type of pyrolysis, including slow, fast, and flash [7,8]. Slow pyrolysis produce in the same amount of gas and liquid. Basically, liquid fuel constitutes the last part of the products of fast pyrolysis. Also, flash pyrolysis produces most of the liquid fuel [9,10].

Several studies have been conducted using RMSW as a resource of raw materials for liquid fuel production. Some studies have focused on converting MPW into liquid fuel [11,12,13,14,15]. Still, others have focused on the use of biomass waste as a resource of raw materials for bio-oil [16,17,18,19,20]. However, the RMSW has a variety of feedstock composition, including biomass, paper waste, Real plastics, rubber, textile, and inorganic wastes. It is not easy to make separation because it is available abundantly in dirty form. Therefore, the research of pyrolysis with RMSW as a feedstock was indispensable. Auxilio. RA et al. (2017) conducted some experiments using single and Real plastic wastes. Their results show that HDPE raw material produces more gasoline and diesel fractions [21]. A. López et al. (2011) and Kyaw. KT et al. (2015) investigated the effects of various types of catalysts on the pyrolysis of plastic waste mixtures. They established that the use of suitable catalysts produce in increased liquid fuel mass yield [22,23]. In the catalyzed pyrolysis, the presence of biomass in Real plastic and feedstock inhibits the influence of catalysts in the degradation process. This problem can be solved by using a higher catalyst ratio [24]. Moreover, the addition of catalyst in Real plastics sample reduces the amount of liquid fuel significantly [25]. In direct and separated catalyst cracking with Real plastics sample, higher gas yields are obtained [26]. However, limited studies have focused on increasing the mass yield of liquid fuels on municipal solid waste with completed mixtures

of MSW. In the previous research, pyrolysis of RMSW with and without and direct catalytic was investigated [27,28]. This study is a continuation of the previous research that aims to increase the mass yield of liquid fuel products using LCD in stage pyrolysis. It involves two types of natural catalysts, including natural zeolite and kaolin. The bed temperature was varied between 200 and 300 °C.

2. Material and Experimental Methods

2.1. Materials

In this study, six types of waste material in municipal solid waste were used, including biomass, HDPE, LDPE, rubber, paper, and textile. This waste is taken directly from the final disposal garbage in Bandung City. The RMSW sample was dried through solar drying for 3-5 days before it was chopped into small pieces between 5–10 cm, which the appropriate size for the reactor capacity. The composition of Real waste includes biomass 34%, Real plastics 52%, paper 9%, rubber 3%, and textile 2%. Furthermore, natural zeolite and kaoline were obtained from a local source in Lampung Province. Zeolite and kaolin were activated thermally at 500 °C for 2 hours to improve the IR active sites and crystallinity. The characteristics of both natural catalysts are based on [29].

Biomass	34%,
Plastics	52%,
Papers	9%,
Rubbers	3%,
Textile	2%



Figure 1. The RMSW sample composition in pyrolysis experimental

2.2. Experimental Methods

Thermal and catalytic cracking were used to investigate the effect of bed temperature and catalyst in the long catalyzer. The pyrolyzer for thermal cracking was performed using a bench-scale reactor made from stainless steel cylinder, 310 mm height, and 160 mm. The reactor had an electrical heating jacket around the cylinder. The pyrolyzer was set vertically, and nitrogen gas was introduced for 3 min from the top. In general, the flow of nitrogen replaces the air inside, creating the necessary vacuum conditions for the pyrolysis reaction. The gas flowed out through the top of the reactor again. The upgrading of the gaseous product from the pyrolyzer was performed in the long catalyzer downstream that was placed before the condenser (Figure 2). The long catalyzer has length and diameter of 100 cm and 10 cm, respectively, having both the top and bottom outlet. Between the pyrolyzer and LCD, a valve that controls the reaction time is installed.

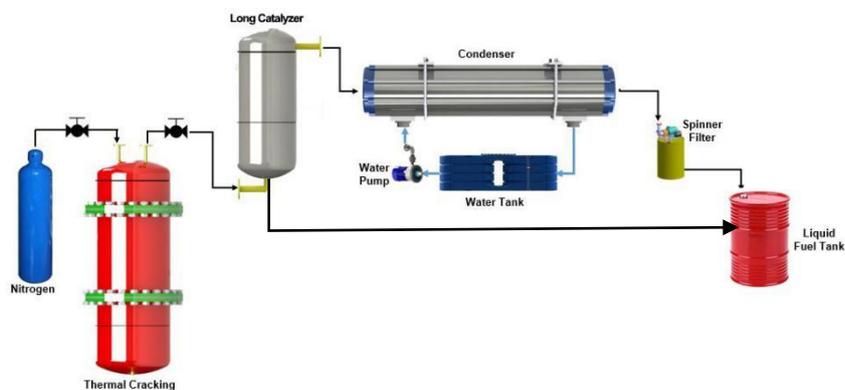


Figure 2. Experimental setup

In the pyrolysis experiment, 500 grams of RMSW sample (unwashed) was loaded into pyrolyzer from the top before heating by electrical heater jacket until the temperature was 500 °C was achieved by thermo controller and held for 60 minutes. Afterward, the temperature of LCD varies from the 200-300 °C. When the reaction time was held for one experiment, the valve control was opened to discharge the gaseous phase from the pyrolyzer to LCD and then to the condenser. Liquid fuel fraction from Condenser flowed to spinner filter and liquid tank. The permanent gaseous fraction from the condenser was burned to avoid environmental pollution. The mass yield of liquid fuel pyrolytic and solid residue were counted by Tora TR-DS11030 of electronic digital scales and then tabulated.

3. Results and Discussion

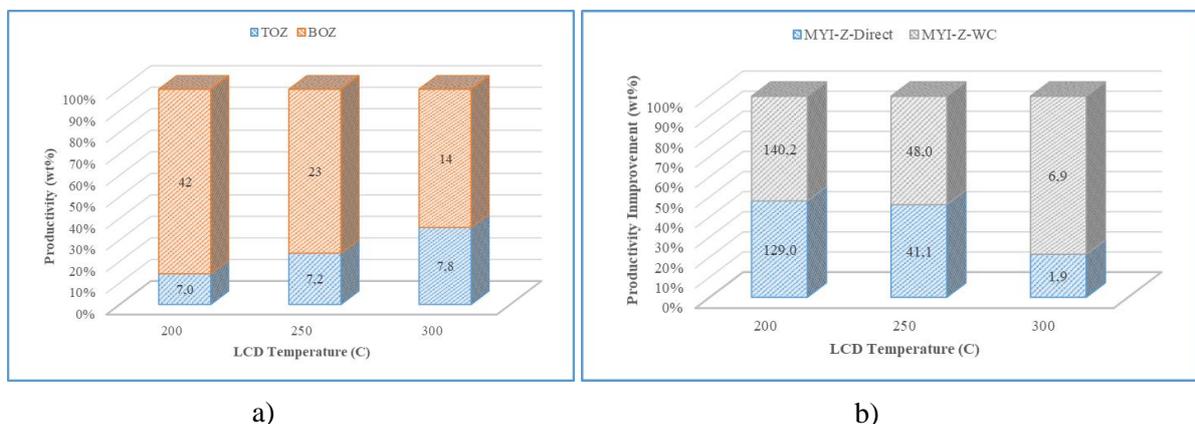
The liquid fuel, gas, and solid mass yields (wt%) obtained using the two pyrolysis methods, and conventional one-step thermal with and without catalyst are presented in Table 1. The catalytic process increased the gaseous and liquid yield compared with non-catalytic pyrolysis. It indicates that catalysts increase the productivity in the pyrolysis process. However, the direct catalyzed pyrolysis is affected by the presence of catalyst particles carried in the gas. Also, LCD presence has a higher yield on liquid fuels compared to direct catalytic cracking. Secondary cracking with the LCD increased the number of short-chain hydrocarbons and was converted into liquid fuel and gaseous fraction. However, the amount of solid residue is significantly reduced.

Table 1. Mass yield pyrolysis

Methods	LCD Temp (°C)	Mass Yield (%)			
		Solid Residue	Fuel on Top	Fuel on Bottom	Gaseous
Without Catalyst	-	32	20.4	-	39.6
Direct Catalytic-Zeolite	-	30	21.4	-	51
Direct Catalytic-Kaoline	-	28.4	23.6	-	49.2
Stage Pyrolysis-Zeolite	200	38,4	7,0	42	12,6
	250	38	7,2	23	31,8
	300	26,6	7,8	14	51,6
Stage Pyrolysis-Kaoline	200	36,8	5,6	21,8	35,8
	250	28,8	6,8	20,4	44
	300	22,6	4,8	24	48,8

In case the temperature on the LCD was increased, the liquid fuel yield is decreased while the gaseous fraction increased significantly. Furthermore, the solid residue was still high, and this is attributed to short reaction time, the presence the biomass feedstock, and impurity in the RMSW sample.

Figure 3. Shows the effect of natural catalyst and bed temperature of LCD on the mass yield and improvement result achieved after the pyrolysis process using an LCD device.



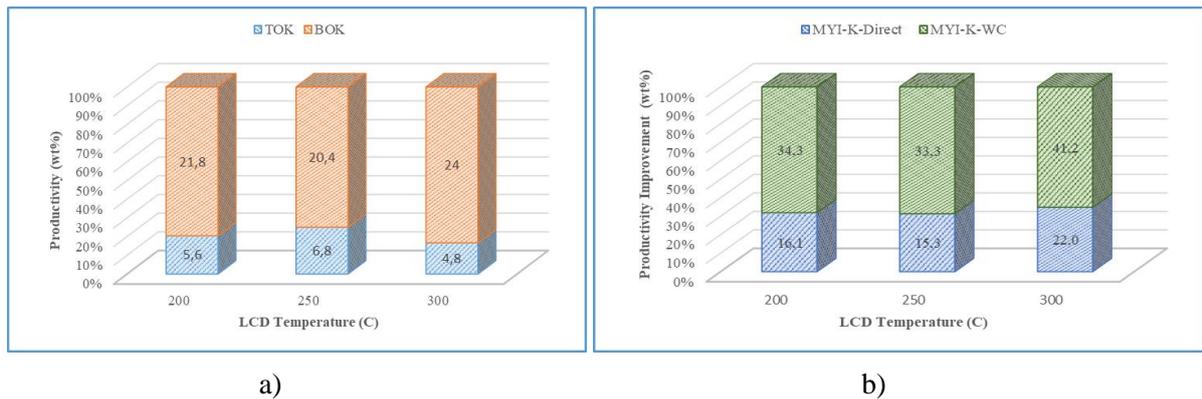


Figure 3. a) Productivity of product, b) Improvement result by the catalyst

In both of graphs, pyrolytic liquid fuel was higher and flowed out on the bottom (BO) compared to the top (TO). The pyrolytic liquid fuel using natural zeolites catalyst has higher yields than kaolin catalysts for all reaction conditions. Therefore, it has better productivity behavior compared to the kaoline catalyst. For zeolite, the maximal yield around 42 wt% was obtained at 200°C and 24 wt% at 300°C for kaolin. At 200 °C of the LCD bed temperature, pyrolytic liquid fuel flowing out at the bottom (BOZ) and top (TOZ) section (Fig. 3a) has sticky behaviour physically, and therefore it is referred to as a wax product [30,31]. TOZ and BOZ can be classified as a long-chain hydrocarbon compound that requires re-cracking. The pyrolytic liquid fuel by kaolin on the top and bottom (TOK and BOK) were more aqueous and classified as short-chain hydrocarbon compounds. The optimum yield of pyrolytic liquid fuel for zeolite is obtained at 250 °C, which is the best result for all experiments on both catalysts.

The comparison of the mass yield of liquid fuel from stage pyrolysis, direct catalytic, and pyrolysis without catalyst shows the pyrolytic liquid fuel increased significantly in both natural catalysts (Fig. 3b). The catalyst allows secondary cracking repeatedly in the LCD and increases the short-chain hydrocarbon compound in the gaseous fraction. In the reaction bed temperature, 250°C was a suitable reaction condition for the pyrolysis of RMSW. However, the GCMS analysis was needed to assess the quality of the pyrolytic liquid fuel obtained.

4. Conclusion

The presence of an LCD equipment equipped by natural zeolite or kaoline on the stage pyrolysis increases the pyrolysis performance. Natural zeolite catalyst has excellent performance compared to natural kaoline catalyst operating on low reaction bed temperature.

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ABBREVIATION

MSW	Municipal Solid Waste
MPW	Municipal Plastics Waste
LCD	Long Catalyzer Downstream
HDPE	High-Density Poly Ethylene
LDPE	Low-Density Poly Ethylene
BOZ	Bottom Outlet with Zeolite catalyzed on LCD [%]
TOZ	Top Outlet with Zeolite catalyzed on LCD [%]

BOK	Bottom Outlet with Kaolin catalyzed on LCD [%]
TOK	Top Outlet with Kaolin catalyzed on LCD [%]
MYI-Z-Direct	Mass Yield Improvement by stage pyrolysis compared with Direct catalytic - zeolite catalyzed [%]
MYI-Z-WC	Mass Yield Improvement by stage pyrolysis with zeolite catalyzed compared with Without Catalysts [%]
MYI-K-Direct	Mass Yield Improvement by stage pyrolysis compared with Direct catalytic - kaolin catalyzed [%]
MYI-K-WC	Mass Yield Improvement by stage pyrolysis with kaolin catalyzed compared with Without Catalysts [%]
GCMS	Gas Chromatography-Mass Spectrometry

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