FUEL OIL PRODUCTION

by Anton Irawan

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Fuel oil production from thermal pyrolysis of packaging plastic

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A Irawan[1*], Y Bindar[2], T Kurniawan[1], H Alwan[1], A Hidayat[1] and A H I Putri[1]
[1] Chemical Engineering Department- Faculty of Engineering- Universitas Sultan Ageng Tirtayasa, Jl. Jendral Soedirman Km 3 Cilegon Banten – Indonesia 42135
[2] Chemical Engineering Department- Institut Teknologi Bandung, Jln Ganesha 10 Bandung – Indonesia

[*]E-mail: anton11975@yahoo.com

Abstract. Nowadays, Plastics are widely used mainly as packaging. With the increasing use of plastic, the amount of plastic waste was increasing. Plastic was a material that was difficult to decompose naturally so that plastic waste will continue to accumulate. This condition will disturbance the environment. In other conditions, energy needs, especially fuel oil, are increasing but the availability of crude oil was limited. This condition requires alternative fuels to maintain the availability of fuel oil for the needs of industry, vehicles and households. Both of these conditions can be related to convert plastic waste into fuel oil through the pyrolysis process. Pyrolysis of plastic waste can be done as thermally and catalytically. The thermal plastic pyrolysis process can be carried out at temperatures between 300-500ºC and pyrolysis time between 30-60 minutes. The results of pyrolysis of plastic waste produce fuel oil which can be used as fuel in industries such as boilers. Yield of pyrolysis plastic polypropylene (PP) was higher than plastic polyethylene (PE). The physical properties of oil plastic pyrolysis PE and PP like gasoline but the flash point was lower than gasoline.

1. Introduction

Plastic was a material that was widely used today because it was lightweight, elastic and easily shaped. Many sectors used plastic materials such as electronics, vehicles, construction and food. With many sectors using plastics, the amount of plastic waste generated was increasing. Plastic is a material that is difficult to decompose naturally in a fast time so that plastic will increasingly accumulate and disturb the environment. Data from the Ministry of Environment of the Republic of Indonesia in 2014 showed that the amount of plastic waste is around 8.96 million tons / year and that number will increase along with the increasing population with an estimate in 2019 will be 9.52 million tons / year [1].

In other conditions, the national energy demand increased so that imports of crude oil and fuel have also increased. In 2016, Indonesia imported crude oil amounting to 148,361,447 barrels and imported fuel oil as much as 22,801,063 kilo litres with the amount of foreign exchange that must be spent more than 200 trillion rupiahs [2]. This condition caused the Indonesia government to look for alternatives to substitute petroleum fuels ranging from renewable energy fuels or the reuse of products from fossil fuel materials to produce energy such as plastic.

Plastic can be converted into fuel oil by various alternative processes such as gasification and pyrolysis. Pyrolysis was the most optimal method because of the high conversion rate, the highest amount of energy obtained, low processing temperature and low investment costs [3]. Pyrolysis was

carried out at temperatures around 300 - 600oC without using oxygen. Plastic pyrolysis can produce solid, liquid and gas fuels that depend on the plastic types, temperature, pressure, heating rate and length of the pyrolysis process [4].

Polyethylene (PE) and polypropylene (PP) are the 2 types of plastic most widely used, especially for packaging. Pyrolysis oil from plastic can be obtained depended on the type of the plastic polymer. In slow pyrolysis for PP plastic with a temperature of 300-400oC and pyrolysis time of about 8 hours can be produced 82% of pyrolysis oil and further refining can produced gasoline oil with the highest-octane number and low viscosity [5]. The length of time of pyrolysis becomes a consideration because the energy consumption of the pyrolysis process will increase at a long time of pyrolysis. This condition was influenced by pyrolysis temperatures because high pyrolysis temperatures will also increase energy consumption. In polystyrene pyrolysis with a temperature of 450°C and pyrolysis time 75 can be produced yield of pyrolysis oil up to 80% [6].

Plastic can be converted to oil by thermally and catalytically through pyrolysis process. Thermal pyrolysis of plastics at temperatures around 350 – 900°C resulted pyrolysis oil with low octane numbers and many impurities. [7]. At low temperature pyrolysis around 460°C, plastic pyrolysis produced highly viscous oil with a high content of long hydrocarbons and while plastic pyrolysis around temperature 600°C produced lower amount of aromatic liquid. The optimal conditions of plastic pyrolysis were carried out at a temperature of 500°C for 15-30 minutes. [8]. Thermal pyrolysis can produce pyrolysis oil up to 95% but the quality of the oil contained many impurities [9]. Under these conditions it is necessary to conduct research to obtain suitable operating conditions for pyrolysis of PE and PP plastics in a pyrolysis reactor. In addition, the condition of bed reactor illustrated by the porosity of the pyrolysis reactor needs to be investigated for its effect on the yield of plastic pyrolysis oil because the reactor bed pyrolysis will affect heat transfer from the heat source to the plastic material and between plastic materials.

2. Experimental

2.1 Raw material

In this study, polyethylene (PE) and polypropylene (PP) plastics were used. PE and PP plastic types were used in this study with the consideration that the two types of plastic are widely used as plastic packaging. This packaging plastic become waste that pollutes the environment. PE was produced from polymerization of ethylene monomers and PP is produced from polymerization of propylene monomers. The PE and PP plastic were reduced to an average size of 2 × 2 cm. The amount of plastic was prepared for variations of 150, 200 and 250 grams.

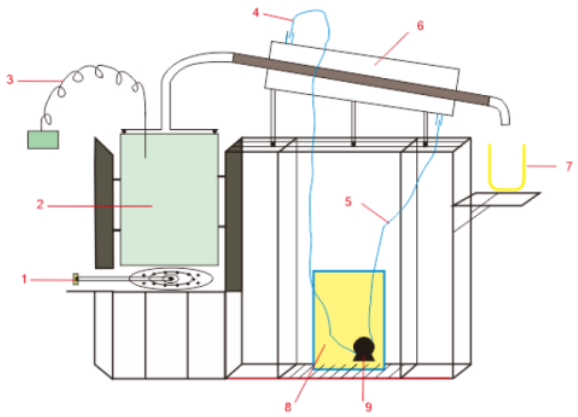

Figure 1. Reactor schematic of plastic pyrolysis experiment.

2.2 Pyrolysis of plastic

PE and PP plastics was added to the pyrolysis reactor (Figure 1.) of 150, 200 and 250 grams with a temperature increase of 10 °C / min. Then pyrolysis with a certain temperature that was 300, 350, and 400 °C. After PE and PP plastic pyrolysis has been carried out then the yield of the product pyrolysis were calculated and the flash point, viscosity, and density was analysed.

3. Results and Discussions

In this study, the results were shown in the effect of temperature and density on oil yield from the PE and PP plastic pyrolysis. The temperature was varied because the pyrolysis was greatly influenced by the temperature to break the chain of monomers into gas components - gas that was easily condensed. Then the reactor bed density was shown in the form of porosity which gives the understanding that large porosity means small density and vice versa small porosity indicates large density.

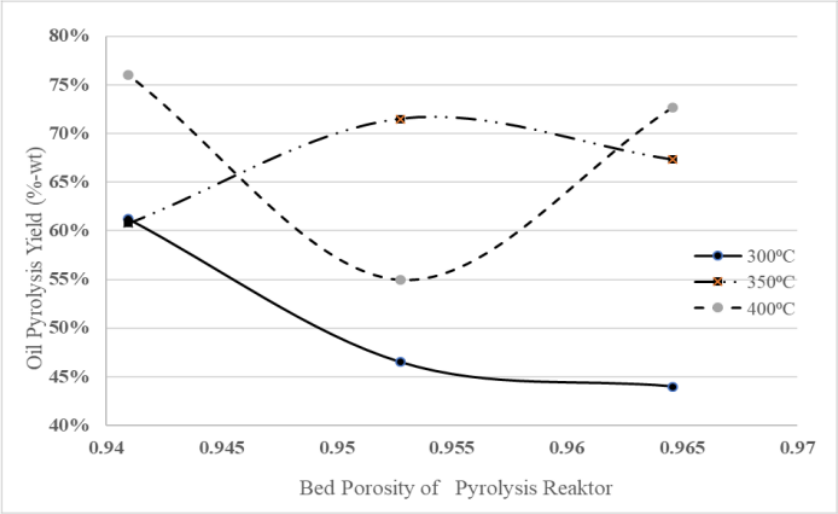

Figure 2. Influence of bed porosity and pyrolysis temperature (°C) to the oil pyrolysis plastic yield (%-wt.) for polyethylene pyrolysis.

The influence of the temperature of the pyrolysis process was carried out with 3 variations, namely 300, 350 and 400°C. The yield of plastic pyrolysis oil increased with the higher temperature as shown by the oil yield of PE and PP plastic pyrolysis (Figures 2 and 3). This condition showed that the high temperature of pyrolysis rector will supply high heat to the plastic. With the increase of heat received by plastic, it would be easier for PE and PE plastic polymers to be decomposed into gas-gas which will be easily condensed. Even in PP plastic pyrolysis can be obtained yield pyrolysis oil up to more than 75% (Figure 3).

Yield in PP plastic pyrolysis was higher compared to PE plastic because the decomposition of gas-gas in PP was more easily condensed compared to PE which was expected to produce lighter gas and difficult to condense. But in PP plastic pyrolysis there was an instability in oil yield of plastic pyrolysis (Figure 3) because the PP plastic cracking process was more difficult than PE pyrolysis. With the same PE and PP plastic feed sizes of 2 x 2 cm so that PP plastic which has a larger molecular monomer would take longer to break the chain of its constituents. In future studies, it is necessary to observe the effect of the size of the plastic on oil recovery, especially on PP plastic types which can produce more pyrolysis oil and stable (Figure 3).

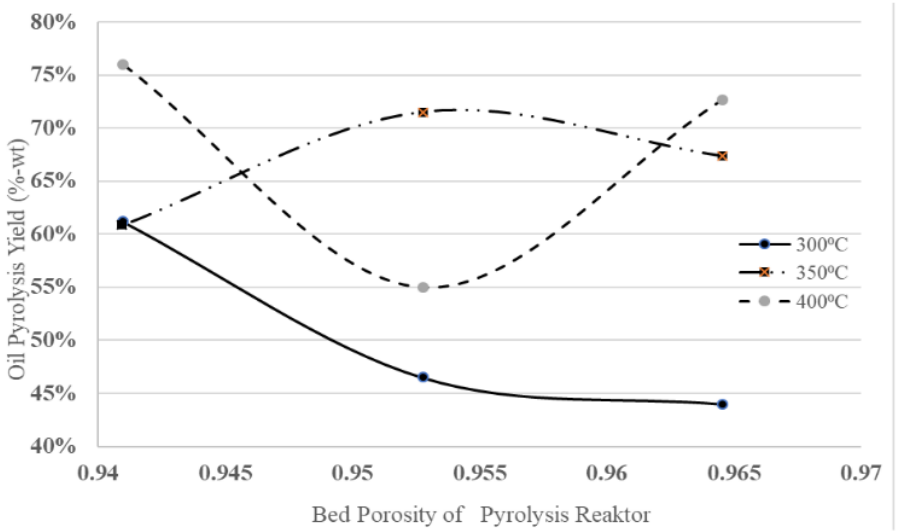

Figure 3. Influence of bed porosity and pyrolysis temperature (°C) to the oil pyrolysis plastic yield (%-wt.) for polypropylene pyrolysis.

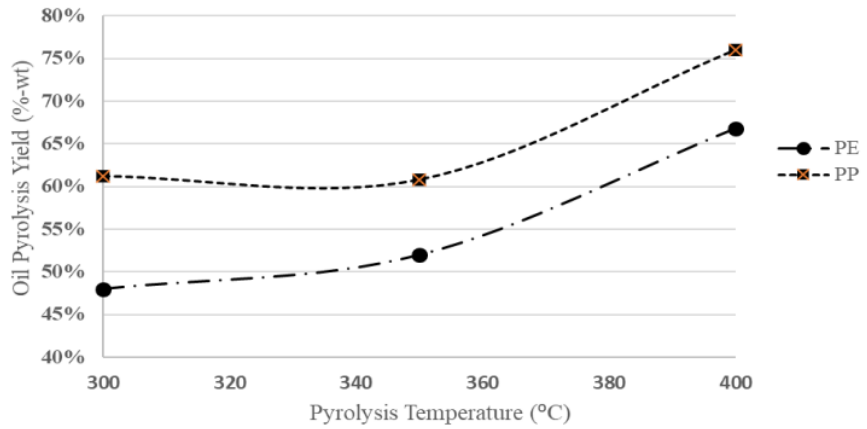

Figure 4. Influence of pyrolysis temperature (°C) to the oil pyrolysis plastic yield (%-wt.) for polyethylene and polypropylene pyrolysis.

Then the effect of porosity bed of the reactor shows that the higher the porosity of the reactor will reduce oil recovery (Figure 3). With the higher bed porosity of the reactor filled with plastic, the distance between plastics was getting farther away from each other. Thus, convection heat transfer would be more dominant than conduction under high bed porosity conditions. At low temperatures (300 and 350°C), porosity of the bed reactor has an influence on the oil yield of plastic pyrolysis. Then at a higher temperature rise (400°C), the temperature of the pyrolysis process was more dominant than the porosity of the bed reactor (Figure 3). However, the pyrolysis temperature and porosity bed in the reactor affect the PE plastic pyrolysis but the PP pyrolysis was more influenced by the PP material factor which has a larger monomer molecule compared to PE. This condition needs to be studied

further to reduce the size of PP plastic so that the pyrolysis of PP plastic will be more stable to produce oil.

The comparison of the yield of plastic PE and PP pyrolysis oil products shows that the PP was more than the PE. From Figure 4, it can be seen that PP plastic can produce up to 75% -weight compared to PE, which is 65% by weight. This condition can be caused the PP plastic pyrolysis process still produces gases which can be easily condensed into plastic pyrolysis oil compared to plastic PE pyrolysis which produces more light gases that are difficult to condense.

Table 1. Physical Properties of Oil Plastic Pyrolysis for PE and PP.

Plastic Mass	**Temperature**	**Polyethylene**			**Polypropylene**		
		Density	Viscosity	Flash Point	Density	Viscosity	Flash Point
gram	°C	gram/ml	mPa.s	°C	gram/ml	mPa.s	°C
	300	0.792	1.06	30	0.774	0.77	30.5
150	350	0.787	0.94	30	0.784	1.05	30
	400	0.804	1.60	30	0.796	1.31	30
	300	0.795	1.11	30	0.786	0.95	30
200	350	0.792	1.20	31	0.790	1.25	30.5
	400	0.807	1.92	31	0.796	1.40	30.5
	300	0.790	1.08	31	0.776	0.95	31
250	350	0.792	1.22	31	0.791	1.21	31
	400	0.808	1.97	31	0.799	1.69	31
Commercial Standard Value (ASTM 1979)	Gasoline [10]	0.780	1.17	42	0.780	1.17	42
	Diesel [10]	0.807	1.9 -4.1	52	0.807	1.9 -4.1	52

Then the physical properties of pyrolysis oil PE and PP was analysed to obtain data on density, viscosity and flash point. Table 1 shows that the density of PE and PP approaches the types of gasoline and diesel oil fuels. Then the value of viscosity at low temperatures (300 and 350°C) approaches the viscosity of gasoline but at high temperatures (400°C), PE and PP oil products have high viscosity. This condition can be caused because at high temperatures, the breaking up of the monomers is more so that it causes some heavy components of the monomers to condense into plastic pyrolysis products.

Flash point of fuel becomes the determinant for the ease of burning of a fuel. Fuel oil for gasoline has a standard flash point temperature of 42°C [10] and diesel 52°C [10]. However, gasoline was more flammable compared to diesel. In this experiment the flash point values were obtained between 30-31°C (Table 1) so that the pyrolysis oil of plastic PE and PP would be more flammable compared to gasoline. This condition will certainly be dangerous to be used as vehicle fuel so that plastic pyrolysis oil must be further processed to get a higher flash point value.

4. Conclusions

Pyrolysis of PE and PP plastic can produce oil with the highest oil yield above 75%. Bed reactor temperature and porosity are very influential in the oil yield for pyrolysis of plastic PE. PP plastic pyrolysis is still affected by the plastic conditions compared to the operating conditions at the reactor. The pyrolysis oil obtained was like gasoline oil, both oil from pyrolysis plastic PE and PP with flash points lower than the gasoline standard.

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