Green Product of Liquid Fuel from Plastic Waste by Pyrolysis at 900 °C

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Abstract: Alternative treatments to convert plastic waste into fuel currently receive great attention from researchers worldwide. The objective of the research is to obtain liquid fuel from pyrolysis of waste plastics that is safe for humans as well as environment, with a heating value and fuel quality meet the standardized compliant. The method used for the research is plastic waste pyrolysis heated at 900 °C, and the resulting vapor is condensed through a crossflow condenser. The method resulted in a liquid fuel with a calorific value of 46,848 J/g, which is greater than that of plastic waste processing at a temperature of 425 °C that is only 41,870 J/g. In addition, the nature of current method for treating plastic waste is considered more secure than that of plastic waste processing at the temperature of 425 °C. The reason for this is the fact that the percentage of compounds that could potentially be carcinogenic (boric acid and cyclopentanone) is reduced.

Key words: Plastic waste, fuel, pyrolysis, green product.

1. Introduction

As the highest consumption of fossil fuels country, Indonesia consumed petroleum for approximately 1.6 million barrels per day in 2005, while in 2006, it reached 1.84 barrels per day. Other countries such as Japan and Germany equally consume only less than 1 million barrels per day [1]. In 2013, the United States produced about 30 million tons of plastic each year total, but with only about 4% are recycled [2]. In addition to producing energy, the combustion of fossil energy sources also releases gases, including CO₂ (carbon dioxide), NO_x (nitrogen oxides), and SO₂ (sulfur dioxide), which causes air pollution [3]. So it is highly necessary to find alternative fuels to be widely used that are environmentally friendly.

Research developed at this time can be used as fuel instead of fossil fuels [4]. Previously, in 2009, Anggono [1] has conducted a research on the type of plastic waste from food packaging (Low Density

Polyethylene or LDPE) at a temperature of 425 °C heating, and the results show that compounds have properties such as flammable acetone and cyclopentanone (1.68% area) [5]. In the same year, Damanhuri [6] stated that the cyclopentanone compounds were cyclic ketone compounds that potentially exist carcinogenic gas (toxic). In addition, boric acid is also harmful if it is accidentally breathed in, since it may irritate mucous membranes that showed by sore throat, coughing, and short breathing.

Basing on the background, Indonesia contributed to the decline in petroleum reserves and also the problem of energy crisis faced by the world today. Therefore, this study aimed to obtain liquid fuels resulted from pyrolysis of waste plastics that is safe for humans and environment, with a heating value and fuel quality that meet standardized-compliant.

2. Material and Method

Shredded plastic waste and included in the converter and heated to a temperature of 900 °C, and the resulting vapor is condensed through a crossflow condenser.

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Fuel oil is produced at the heating temperature of 900 °C, and the heating value is tested using Bomb Calorimeter and testing GC (gas chromatography). Tests conducted uses the calorific value-bomb calorimeter contained in Energy Conversion Engineering Laboratory, Polytechnic of Jakarta. GC-MS (GC mass spectrometry) analysis method is used to read both spectra contained in the combined method.

GC test results if there are samples contain many compounds, which are evident from the many peaks (peak) in the GC spectra. Based on the data retention and time is already known from the literature, we know what compounds were present in the sample [7]. Next step is to incorporate the compound into the alleged mass spectroscopy instruments. This can be done because one of the uses of GC is to separate the compounds of a sample. After that, the results can be obtained from MS spectra at different charts.

3. Result and Discussion

Pyrolysis process starts at temperatures around 230 °C [8] and happens in the absence of oxygen for thermal decomposition of organic material [9, 17].

Plastic is a synthetic organic material or semi-synthetic organic materials derived from petroleum and natural gas of plastic products, resulting in PET (polyethylene terephthalate), HDPE (high density polyethylene), PVC (polyvinyl chloride), LDPE (low density polyethylene), PP (polypropylene), PS (polystyrene), polyurethane and polyphenols, generating plastic waste that consists around 50%-60% of polyethylene, 20%-30% of polypropylene, 10%-20% of polystyrene, and 10% of polyvinyl chloride [10, 17]. For PE (polyethylene) medium and high density polyethylene, the melting point ranges from 120 °C to 135 °C. Low density polyethylene melting point ranges from 105 °C to 115 °C. HDPE is characterized by a density that exceeds or equals to 0.941 g/cm³. HDPE has a low degree of the ramifications and inter-molecular [16] strength and very high tensile strength. It functions

Fig. 1 Converter plastic waste into fuel.

as material for milk bottle, bottle/detergent packaging, packaging margarine, water pipes and bins. LDPE is characterized by a density from 0.910 g/cm³ to 0.940 g/cm³. LDPE has a high degree of the long and short chain branching, which means it will not turn into a crystalline structure. It also indicates that LDPE has a low tensile strength. LDPE can be found in the form of container since it is strong and in the form of plastic film applications, such as plastic bags and plastic wrap. LLDPE (linear LDPE) is characterized by a density between 0.915 g/cm³ and 0.925 g/cm³. LLDPE is a linear polymer with a short chain branching with a significant amount. LLDPE is used as material for cable wrap, toys, packaging caps, buckets, containers and pipe [15].

Sapriyanto [5] has tested a machine to convert plastic waste into fuel. The test material is 1 kg of plastic waste that is heated within 530 °C heating. All kinds of plastic are put into the machine. Then, within two hours, the machine produces liquid fuels as much as 300 mL. The test shows the calorific value of the fuel is plastic waste of 10,519 cal/g or 44,040.95 J/g, equivalent to the heating value of the premium is 10,285 cal/g or 43,061.24 J/g. In the same year, Ramadhan [11] also examined the oil obtained from the pyrolysis process of waste plastic. This study uses two types of plastic as a fixed variable, namely HDPE and LDPE, using the reactor with a diameter of 20 cm and height of 40 cm. Pyrolysis temperature is held at

250-420 °C and the reaction time lasts for 0-60 minutes. Oil produced in the pyrolysis process can be compared to kerosene and oil is a source of valuable chemicals, such as alcohols, organic acids, ethers, ketones, aliphatic and aromatic hydrocarbons. And gas is produced in the form of CO_x , NO_x , H_2 and alkanes [6, 15, 19].

Suryo [12], in his study of the properties of a mixture of waste biomass pyrolysis oil and plastic waste PP (polypropylene), tries to investigate the density, viscosity and heating value. The pyrolysis oil resulted from the research is thus used to boil water on the stove. The efficiency of pyrolysis oil stoves is also tested using standard WBT (water boiling test). The research shows the obtained oil-fired stove efficiency is best at 30% biomass composition and 70% plasticat the temperature of 400 °C.

Based on the decision of the Director General of Oil and Gas in 2008, the Ministry of Energy and Mineral Resources of the Republic of Indonesia, the standards and quality (specification) of fuel, in the form of oil marketed in the country, are as follows [13, 18].

At first, pyrolysis technology is considered as an environmentally friendly method [14] since the method

ultimately produces CO_2 and H_2O , the former is a non-toxic gas. But in its development, the cyclopentanone compounds as the result of the pyrolysis of cyclic ketones can potentially turn into carcinogenic gas (toxic). In addition, boric acid, also harmful if inhaled, can cause irritation of mucous membranes accompanied by sore throat, coughing, and breathing becomes short [3]. Cyclopentanone compounds can be identified through gas chromatography [7, 15, 17, 19].

The calorific value is compared to the value obtained with the standard and quality (specification) of fuel oil type of oil that is marketed in the country (Dept. of Energy and Mineral Resources of Indonesia, 2008) [19], to meet the calorific value of fuel, standards should be above 41,870 J/g. Based on test results, the value of the heat, produced of 11,189 cal/g or 46,848 J/g, thus can meet the standard calorific value of the fuel sold in the country.

Based on the results of testing, the fuel produced at the heating temperature of 900 °C obtained levels of flammable compounds (2-propanone) increases, while potentially carcinogenic compounds (boric acid and cyclopentanone) reduced the percentage.

Table 1 Specifications of fuel oil [18].

No.	Characteristic	Units	Limit				Testing method
			Intermediete fuel oil-1		Intermediate fuel oil-2		
			Min.	Marks.	Min.	Marks.	
1	NilaiKalori	MJ/kg	41.87	-	41.87	-	D 240
2	Densityat 15 °C	kg/m ³	-	991	-	991	D 1259
3	Kinematics Viscosityat 50 °C	mm ² /dt	-	180	-	380	D 445
4	Sulfur contain	% m/m	-	3.5	-	4.0	D 1552/2622
5	Melting point	°C	-	30	-	40	D 97
6	Flashing point	°C	60	-	60	-	D 93
7	Carbon Residual	% m/m	-	16	-	20	D 189
8	Ash contain	% m/m	-	-	-	0.15	D 482
9	Sedimen	% m/m	-	-	-	0.10	D 473
10	Water contain	% v/v	-	-	-	1.00	D 95
11	Aluminium + silikon	mg/kg	-	-	-	-	D 5184/AAS

Source: Director general SK oil & gas, energy and mineral resources, 2008.

Table 2 Test results calorific value (1 gram mass oil plastic).

Calorific value	Unit (cal/g)
BBM plastic	11.189
Premium	11.245
Quality Standards of Ministry of Energy in Indonesia	10.000

Fig. 2 Graphs the GC-MS testing fuel from plastic waste.

Table 3 Data of important compounds of liquid fuels from waste plastics.

No.	Peak	% Area	Expected compounds	Formula
1	1	64.69	2-propanon/acetone	C_3H_6O
2	2	27.08	Boric acid	H_3BO_3
3	3	0.09	-	-
4	4	6.93	Acetic acid	$C_2H_4O_2$
5	5	1.20	Cyclopentanone	C_5H_8O

4. Conclusion

The processing of plastic waste at a temperature of 900 °C produces liquid fuel with calorific value of 46.848 J/g which means that this value is greater than that of the processing of plastic waste at a temperature of 425 °C which results in the calorific value of 41.870 J/g.

Testing the fuel produced GC-MS showed that the levels of potentially carcinogenic compounds (boric acid and cyclopentanone) is reduced so that the percentage of plastic waste at a temperature of 900 °C has more secure properties than that of plastic waste processing at a temperature of 425 °C.

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