Processing Plastic Waste HDPE and PP on Pyrolysis Temperature Using Cu-Al_2O_3 Catalyst Into an Alternative Liquid Fuel

Pamilia Coniwanti[1,*] Fitri Hadiah[1] David Bahrin[1] Liza Novriani[1]
Gracia Mei Lie Justina[1] Robinsyah[1]

[1] *Chemical Engineering Department, Sriwijaya of University,*
Jl. Raya Palembang-Prabumulih KM. 32, Inderalaya, Ogan Ilir 30662, Indonesia
[*]*Corresponding author. Email: coniwantipamilia@gmail.com*

ABSTRACT
The crisis of energy reserves in Indonesia, especially in petroleum and high plastic waste usage, causes a very worrying problem in Indonesia. One way to overcome this problem is to process plastic waste into alternative liquid fuels. This study aims to determine the effect of temperature and the effect of HDPE and PP plastic waste composition on the pyrolysis process using Cu-Al_2O_3 catalysts, as well as to determine the characteristics of the liquid fuel produced, namely density, flash point, heating value, viscosity and hydrocarbon compound content. This research was conducted by pyrolysis method at temperature of 250ºC, 300ºC, 350ºC, and 400ºC and mixtures of HDPE and PP plastic types of 0:100, 30:70, 50:50, 70:30, and 100:0. Liquid fuels approaching the standard premium type fuel is a mixture of HDPE:PP plastic types with a ratio of 50:50 at a temperature of 300ºC with a viscosity of 1.1872 mm^2/s, calorific value of 10213.0953 cal/gr, density of 0.7880 gr/ml, flash point 32,7°C and GC-MS results show the content of hydrocarbon with a value of C_9 - C_{16}.

Keywords: *pyrolysis, HDPE PP plastic waste*

1. INTRODUCTION

Growth in population and economy in the current era of globalization causes fuel demand to increase. The high demand for petroleum fuels that is not proportional to the rate of production, resulting in fossil fuel oil reserves continue to decrease, moreover this petroleum fuel is not a renewable natural resource.

As a result of the depletion of these fuels, alternative energy reserves are needed. This is accordance with Government Regulation 2014 No. 79 concerning the National Energy Policy, to use new renewable energy well known as Energi Baru Terbarukan of (EBT) and to use of fossil energy sources.

Some previous studies that have succeeded in converting plastic waste into liquid fuel through the pyrolysis process include [1] obtained the best quality HDPE and PP plastic pyrolysis products at 350°C and 400°C. [2] which changed polyethylene plastic waste to produce 61% of liquid fuel products at 450°C which is close to the characteristics of Pertamina's biodiesel fuel (66.5°C).

In direct proportion to the high consumption of petroleum, the usage of plastic and various objects which are also made of plastic continues to increase. This results in a very worrying problem in Indonesia. Indonesia has become the number two contributor of plastic waste in the world. From the data obtained by the Central Statistics Agency as Badan Pusat Statistik (BPS) and the Indonesian Plastic Industry Association well known as Asosiasi Industri Plastik Indonesia (INAPLAS) 2018, plastic waste in Indonesia reaches up to 64 million tons per year where as many as 3.2 million tons are plastic waste sent to the sea. There are various kinds of plastic waste that is discarded every day, the type of plastic that is often found is the type of PP plastic (polypropylene) which is ranked top by number and there is also HDPE (High Density Polyethylene) plastic which is often used in packaging products [3].

According [4] one solution to deal with these problems is by converting plastic waste into fuel oil products. So with this method, these two problems can be overcome, namely the danger of accumulation of plastic waste and the recovery of liquid oil fuel. Plastic waste used in research is HDPE (High-Density Polyethlene) and PP (Polypropylene) types, which are carried out by cracking using pyrolysis technology.

Some previous studies that have succeeded in converting plastic waste into liquid fuel through the pyrolysis process include, [1] obtained the best quality HDPE and PP plastic pyrolysis products at 350°C and 400°C. [5] which changed polyethylene plastic waste to produce 61% of liquid fuel products at 450°C which is close to the characteristics of Pertamina's biodiesel fuel (66.5°C). [4] about processing PP, PET and PE plastic waste into fuel oil and its characteristics. The aim of this research was to determine the effect of temperature and the effect of a mixture of plastic waste raw materials and to determine the characteristics of liquid fuels produced in the HDPE and PP plastic waste pyrolysis process in the HDPE and PP plastic waste pyrolysis process on the quality of liquid fuels obtained.

2. MATERIALS AND METHODS

Preparation of Al_2O_3 catalyst was carried out by impregnation of Cu metal on Al_2O_3.$CuSO_4 5H_2O$ As much as 2 grams are dissolved in distilled water, then stirred using a spatula. Then added as much as 25 grams of Al_2O_3 soaked in $CuSO_4$ solution $5H_2O$ and the mixture is heated.

After obtaining a sample of Cu-Al_2O_3 filtered and washed with aquadest. Dry the sample in the oven, then keep it in a dry and closed place [6]. Raw material in the form of 500 gr HDPE and PP plastic waste is put into the reactor with a ratio of 0:100. Cu-Al_2O_3 catalyst is put into the process as much as 2% of the mass of the raw material. The reactor is closed tightly and connected to the condenser. The cooling water pump is turned on to drain cooling water to the condenser. The reactor heater is turned on with a temperature of 250°C and cracking time is 60 minutes. Liquid pyrolysis result are stored in a sample bottle for testing. The pyrolysis process is repeated by varying the cracking temperature of 300°C, 350°C, and 400°C and ratio of plastic waste raw materials of 30:70, 50:50, 70:30, and 100:0

3. RESULT AND DISCUSSION

Cracking process is the decomposition of molecules of heavy oils or which have high boiling points into lighter components that have low boiling points. Cracking process carried out is to break the chain of polystyrene bonds shorter.

3.1. Fuel Viscosity

From various variations of the composition of HDPE and PP raw materials at various temperatures, the viscosity analysis results can be seen from Figure 1. below:

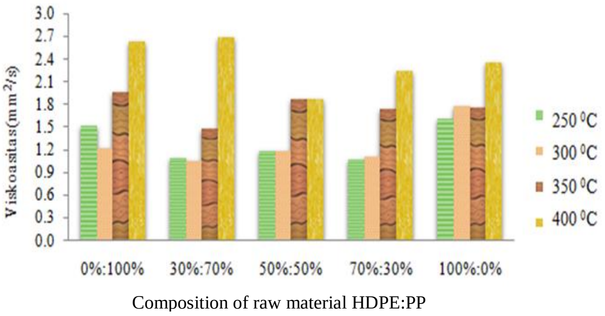


Figure 1 Graphic on the Effect of Raw Material Composition and Cracking Temperature on Fuel Viscosity

Based on Figure 1 it can be seen that viscosity tends to increase with increasing temperature. This is because high temperatures produce oil with a longer carbon chain because at high temperatures it is able to crack the reactants into more long chain hydrocarbons. The longer the chemical structure bonds, the greater the viscosity [7].

Based on the analysis of the viscosity of liquid fuel products, the highest viscosity value was obtained in the composition of HDPE 30%:PP 70% at a temperature of 400°C which is 2.6847 mm^2/s and the lowest value at the composition of HDPE 30%:PP 70% at a temperature of 300°C that is 1,0551 mm^2/s. When there is more PP plastic composition than HDPE plastic, the oil produced will be thicker. This is because PP plastic has a longer chemical structure bond so that the product viscosity is higher. This results in the need for higher temperatures for cracking process with PP raw materials [8].

3.2. Fuel Calorific Value

The heating value is the amount of heat produced from the combustion process of a certain amount of fuel with air / oxygen. In order to get energy from processing, the waste must have a high heat or heat value. Data on the results of the heating value of raw material composition and temperature are shown in Figure 2. below:

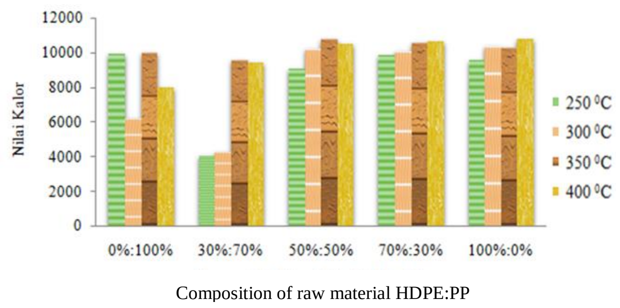


Figure 2 Graphic on the Effect of Raw Material Composition and Cracking Temperature on Calorific Value of Fuel

The heating value produced based on temperature variation is needed to be stable, only at a temperature of 250ºC the heat value produced is on average lower than other variations. The result of the heating value issued by the carbon content in the fuel, the higher the carbon content and hydrogen in the fuel, the higher the heat value. The composition of raw materials used can affect the distribution of the number of C atoms needed in the hydrocarbon composition of pyrolysis products [9].

3.3. Fuel Density

From various variations of the composition of HDPE and PP raw materials at several temperatures, the density analysis results from Figure 3 below can be seen:

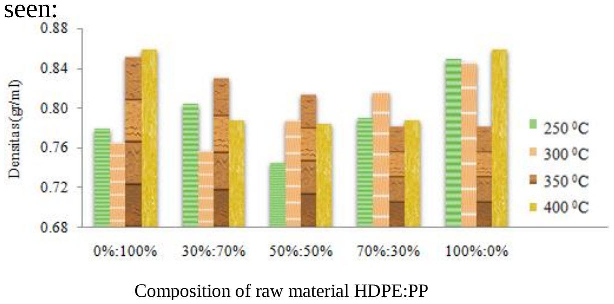


Figure 3 Graphic on the Effect of Raw Material Composition and Cracking Temperature on Fuel Density

Based on the analysis of fuel density, the highest value was obtained in the composition of HDPE 0%:PP 100% (400ºC) of 0.8596 gr/ml and the lowest value in the composition of HDPE 50%:PP 50% (250ºC) of 0.7446 gr/ml. Density is an indicator of the amount of impurities produced by the reaction. If the density of a fuel exceeds the provisions, it will increase engine wear and cause engine damage [10].

3.4. Fuel Flash Point

The flash point is the lowest temperature point at which the fuel can ignite under certain conditions at a pressure of one atmosphere [11]. Measuring the flash point requires an ignition source. At the flash point, the steam can stop to burn when the ignition source goes to. The ignition point is affected by the content of the fuel. The data of the flash point test results can be seen in Figure 4. below:

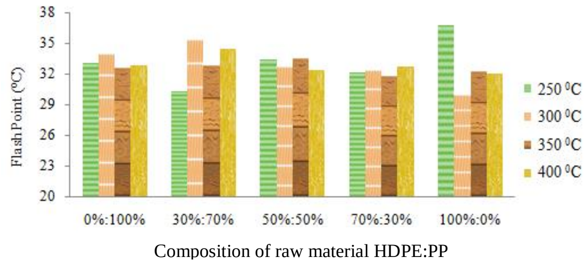


Figure 4 Graphic on the Effect of Raw Material Composition and Cracking Temperature on Fuel Flash Point

Based on Figure 4 the flash point analysis results above, the effect of the composition of the plastic mixture and the temperature showed that the results were not too significant to the value of the flash point. The flash point obtained has a temperature value above room temperature and is still below the standard temperature value of premium types which is 43ºC. From the above data the results of the fuel analysis are considered flammable because they are in the low temperature range.

3.5. Fuel Volume

The liquid volume shows the difference in the number of products converted to various plastic material mixes and temperatures, thus showing the number of hydrocarbon chains which are cracked in the form of heavy fractions then condensed simultaneously when the gas is formed as a result of heating at the reactor. Data on the results of liquid volume from a mixture of plastic materials and temperature can be seen in Figure 5 Below:

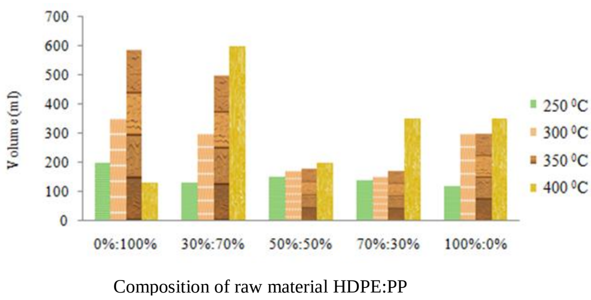


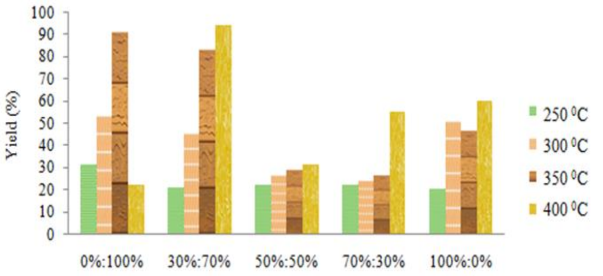
Figure 5 Graphic on the Effect of Raw Material Composition and Cracking Temperature on Volume

Based on Figure 5 above the liquid volume tends to increase with increasing temperature. Degradation of the plastic mixture begins at temperatures above 250ºC. In HDPE: PP 30%:70% plastic mixture with 400ºC temperature variation, the best volume is 600 ml. When the temperature is raised it will accelerate the process of degradation or breakage of plastic hydrocarbon chains so that it increases the volume of liquid resulting from pyrolysis.

The composition of the most PP material produces more liquid volume as well. This happens because the PP hydrocarbon chain fraction is more swollen than the HDPE hydrocarbon in these circumstances. Then, when there are more HDPE plastic raw materials compared to PP plastic, the resulting liquid volume tends to decrease due to the denser HDPE structure making it more difficult to swell than PP plastic.

3.6. Fuel %Yield

Cracking products are in the form of a liquid resulting from condensation of hydrocarbon vapor derived from plastic. The liquid is in the form of liquid fuel which is still mixed, such as the fraction of gasoline, diesel or kerosene. The effect of raw material composition and cracking temperature on fuel yield is shown in Figure 6 Below



Composition of raw material HDPE:PP

Figure 6 Graphic on the Effect of Raw Material Composition and Cracking Temperature on Fuel %Yield

Based on the analysis results it can be seen that 30% HDPE: PP 70% (400°C) yields a yield of 94.54%. The yield produced will tend to increase with increasing temperature. This statement was also stated by [12] that as the temperature increases, more bonds are broken and affect the number of products which are increasing and yields are also increasing. This is due to the lowering of the plastic cracking process, resulting in a wax product consisting of carbonated paraffin and charcoal (char) left behind in the reactor [13].

3.7. Gas Chromatography Mass Spectroscopy Analysis

Samples with 70% HDPE composition: 30% PP at 300oC and 50% HDPE composition:50% PP at 300ºC temperature have the characteristics that most closely match the physical properties of standard fuels. Both samples were analyzed for their compound content using Gas Chromatography Mass Spectrocopy (GC-MS). Based on the analysis results obtained the main components in 70% HDPE samples: 30% PP at a temperature of 300ºC (D2) in the form of a hydrocarbon compound with a C_{10}-C_{25} value while the results of the analysis of the main components in a 50% HDPE sample:50% PP at a temperature of 300ºC (C_2) is a hydrocarbon compound with a value of C_9-C_{16}. This shows the compound content in the C_2 sample has similarities with the compound contained in gasoline, while the D2 sample has similarities with the compound contained in diesel. Where the gasoline fraction has a C_5-C_{12} hydrocarbon value while the diesel fraction has a C_{14}-C_{20} hydrocarbon value.

4. CONCLUSION

Base on result obtained we can conclude that:

1. HDPE and PP plastic pyrolysis produces the best quality products at temperatures of 300ºC and 350ºC, while at temperatures that are too high or low the quality of fuel products is not good.
2. Raw materials with higher amount of HDPE in the pyrolysis process producing products with characteristics that are closer to the standard compared to raw materials that have more PP amount.
3. The characteristics of the resulting pyrolysis product are close to those of premium and diesel fuels.
4. The closest result to the standard is a sample with a ratio of 50% HDPE: 50% PP at 300ºC cracking temperature with a viscosity of 1.1872 mm2/s, a calorific value of 10213.0953 cal/gr, density of 0.7880 gr/ml, and a flash point of 32.7ºC.

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