Pyrolysis of Polypropylene Plastic Waste into Liquid Fuel

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Pyrolysis of Polypropylene Plastic Waste into Liquid Fuel

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Abstract. Plastic is overused in every life application resulting in the accumulation of plastic waste that takes a long time to decompose. An alternative way of handling plastic waste today is to convert plastic waste into fuel oil or called plastic pyrolysis process. Pyrolysis is a chemical decomposition of organic matter through a process of heating without or little oxygen in which the raw material will break the chemical structure into a gas phase. One of the factors affecting the pyrolysis process is the heating temperature in the reactor. In this research, the design of the plastic waste pyrolysis tool using the thermal cracking method with a capacity of 500 grams using infrared heating element. The raw materials used are Polypropylene type plastic. The independent variables are temperature variations in the reactor, i.e., 250°C, 300°C, and 350°C. The dependent variable is the mass of plastic waste, operating time, and operating pressure. From the research results, the higher the heating temperature in the reactor, the higher the % yield, density, specific gravity, and volume of liquid product produced. Conversely, the higher the temperature, the lower API Gravity, Heating Value, and Flash Point are

1. Introduction

Waste is the biggest problem that human faced nowadays. The cities in the world produced 1.3 billion ton/year of wastes. Based on Department of Environmental and Hygiene data, shown that Indonesia produced 10.95 million pieces/year/100 stores plastic bag waste [1]. This fact placed Indonesia as the 2nd rank country to produce plastic bag to the sea with 187.2 million tons waste in the world, behind China with 187.2 million tons plastic waste [2]. Based on Department of Environmental and Hygiene Palembang data, the average of waste production is 800-900 ton and can increase to 1200 tons during the holiday. Part of the waste is consisting of plastic waste.

Plastic is the macromolecule that formed by a polymerization process, which is a combination of some monomer through the chemical process into the bigger molecule called polymer [3]. The use of plastics is needed almost in every aspect because of its advantages, such as lightweight, strong structure, anti-corrosion, and transparent. The importance of plastic used in every aspect causing the accumulation of plastic waste bag that hard to be decomposed for a long time.

Popular plastic waste treatment is 3R, (reuse, reduce, recycle). Reuse is repeatedly using items made of plastic. Reduce is reducing the use of plastic made items, especially for disposable items. Recycle is recycling items made of plastic. Each waste treatment had some disadvantages. The disadvantage of reuse is the certain items made of plastic, such as plastic bags if used many times will not be suitable for use. Also, some type of plastic is not good for health. The downside of reducing is that there must be cheaper and more practical plastic replacement items. While the weakness of the recycle is that the plastic that has been recycled will decrease in quality. Destruction of plastic waste by combustion (incineration) is less effective and risky because by burning the emergence of pollutants from exhaust emissions (CO2, CO, NOx, and SOx) and some other pollutant particulates. So that other processing method are needed to process plastic waste. Another alternative for handling plastic waste that is currently being researched and developed is to convert plastic waste into fuel oil or also called the plastic pyrolysis process. Pyrolysis is chemical decomposition of the organic compound through the heating without or with low oxygen that raw material will change its phase to gas. This process affected by some factors, such as temperature and process time of pyrolysis, type of catalysts, type of reactor, operation pressure, and many more. These factors will influence the product of pyrolysis.

Based on the previous research is known that heating temperature significantly influences the result of plastic waste pyrolysis product [4-5]. A heat source that is used on those researches is LPG. For this reason, in the design of the plastic waste pyrolysis device that the author made, infrared heaters will be used. It is hoped that the heating process can take place more quickly and efficiently. In addition, to facilitate the cleaning of the pipe due to the wax that appears after the process, a backwash flow pipe is designed.

2. Materials and Methods

The design of plastic waste processing equipment consists of a reactor made of stainless steel 15 cm in diameter with a height of 50 cm, this reactor is also coated with asbestos and aluminium to withstand the heating produced by three Infrared heaters. In addition there is also a pre-gauge on the top of the reactor to determine the pressure contained in the reactor along with a pipe equipped with a flange to facilitate opening the reactor lid. At the reactor output pipe there is a Ball Valve to regulate the gas output produced from heating plastic waste.

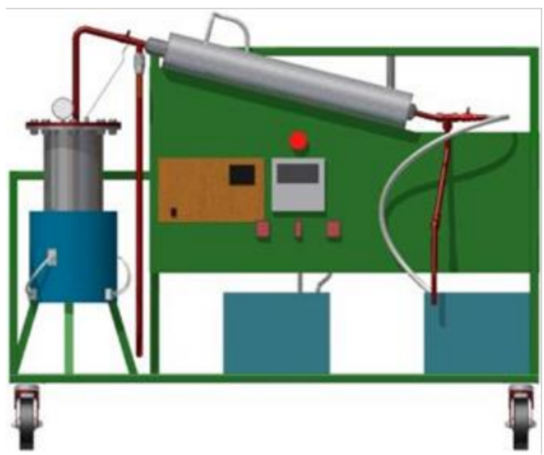

Figure 1. Pyrolysis Equipment Scheme

The reactor gas output will then be condensed into a liquid phase in the condenser. The type of condenser used is Shell and Tube with the type of Counter Flow. The gas from the reactor is inside the pipe while outside the pipe is cooling water. The pipe inside the condenser is made of a spiral with a length of 56 cm. The reason for the spiral pipe is that the cooling process in the condenser can run optimally because of the longer pipe flow. Cooling water comes from the water in the reservoir which is cooled by the chiller and then pumped towards the condenser. The container has dimensions of 30 cm x 18 cm x 23 cm. Figure 1 is the design of a plastic waste pyrolysis device.

3. Results and Discussion

From the results of testing the plastic waste pyrolysis tool can be seen in Table 1. In this test 500 grams of Polypropylene (PP) plastic waste were used for one run with temperature variations in the heating process in the reactor, namely 250°C, 300°C, and 350°C. Then the pyrolysis oil will be analyzed for its characteristics as in Table 2.

Table 1. Waste Plastic Pyrolysis with Temperature Variation on Reactor Result Data

No.	Plastic Waste Mass *Polypropylene* (gr)	Operation Temperature (°C)	Time (Minute)	Operation Pressure (kgf/cm2)	Liquid Product Produced	
					Volume (ml)	Colour
1		250			45	Yellow
2	500	300	60	1,5	55	Deep Brown
3		350			70	Black

Table 2. Pyrolysis Oil Characteristics Analysis Result Data

No.	Operation Temperature (°C)	Liquid Product Physical Properties			Chemical Properties
		Density (gr/ml)	API *Gravity*	Flash Point (°C)	Heating Value GHV(cal/gr)
1	250	0,767	52,9	36	10928
2	300	0,770	52,2	33	10757
3	350	0,774	51,3	31	10626

3.1. Effect of temperature in the reactor on the volume of liquid product produced and % yield

The highest volume of liquid product is at a temperature of 350 °C as much as 70 ml, while the lowest liquid product volume is 45 ml at a temperature of 250 °C. This condition could be happen because the higher the temperature, the more bonds (hydrocarbon chains) are cut off to increase the liquid product produced. From Figure 2 it can be seen that the increase in heating temperature in the reactor is directly proportional to the volume of liquid product produced.

In Figure 3 it can be seen that the higher the heating temperature in the reactor, the higher the yield. The biggest% yield value was obtained at a temperature of 350°C which was 10.91%. While the smallest % yield at a temperature of 250°C is 9%. The increase in% yield due to pyrolysis of hydrocarbon polymers requires large energy (high temperature). At high temperatures, the hydrocarbon chain will be more easily broken compared to low temperatures. This is in accordance the researcher who explained that the higher the temperature, the more the conversion value produced [6]. Increasing the reaction temperature will speed up the cracking process. The increase in product yield can be interpreted as an increase in cracking reactions that occur. Cracking reaction is an endothermic reaction where this reaction involves breaking the hydrocarbon chain so that the process of breaking a bond requires large heat energy [7].

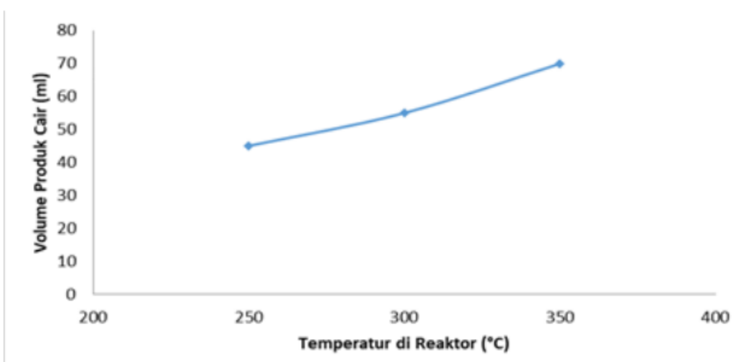

Figure 2. Effect of Temperature on Pyrolysis Liquid Product Volume

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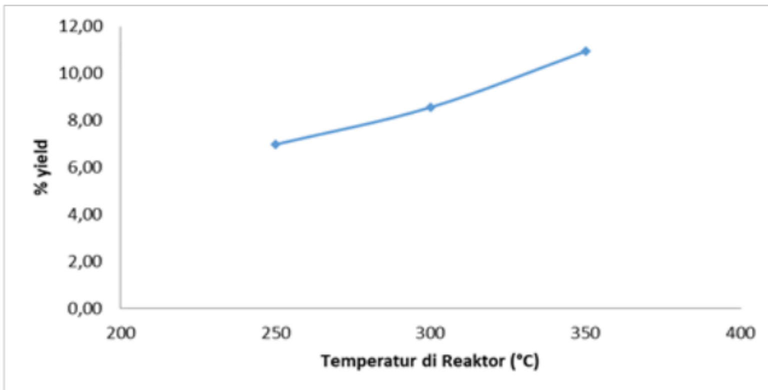

Figure 3. Effect of Temperature Variations on % Yield

3.2. Effect of Temperature in the Reactor on the Density and API of Liquid Gravity Products

The density value is in the range of 0.76-0.77 gr/ml which is in the range of gasoline specifications, namely 0.710-0.780 gr/ml [8]. The greater the temperature, the more weight the liquid product density is due to the heavier molecules that decompose. In Figure 4 it can be seen that the higher the temperature in the reactor, the higher the density of the liquid product produced.

The density value is inversely proportional to the Gravity API as in Figure 5. The higher the Gravity API is, the more valuable petroleum because it contains more gasoline. Conversely, the lower the Gravity API, the quality of oil becomes less good because it contains more wax. Gravity's API value is in the range of 47-49 which is classified as light oil because it has a Gravity API > 20.

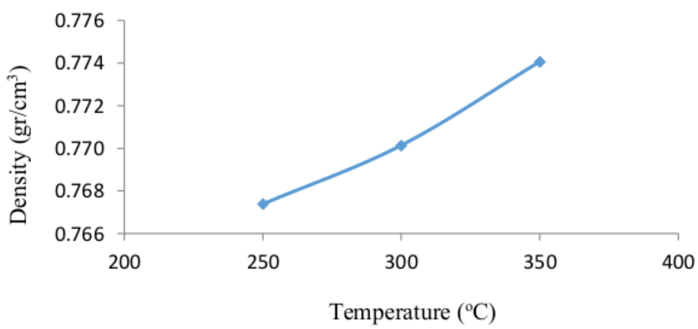

Figure 4. Effect of Temperature Variations on Density

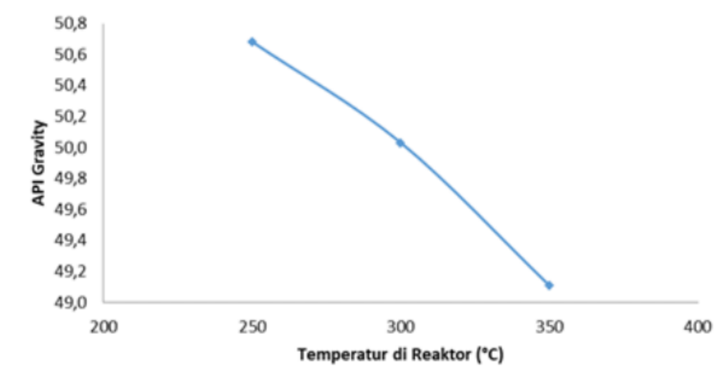

Figure 5. Effect of Temperature Variations on API Gravity

3.3. Effect of Temperature in Reactor on Heating Value

The higher temperature in the reactor, the lower liquid product heating value produced. Heating value range that produced is 10600-10900 cal/gr, based on the diesel fuel heating value, which is 10.700 cal/gr [8]. Figure 6 explained the effect of heating temperature in the reactor on the heating value of liquid product produced.

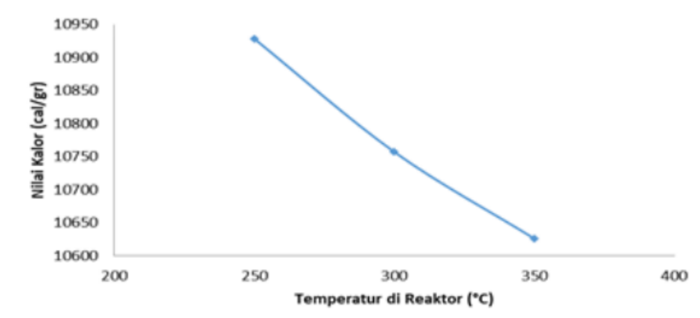

Figure 6. Effect of Temperature Variations on Heating Value

3.4. Effect of Temperature in Reactor on Flash Point

This is due to the higher pyrolysis temperature; the more intense the fire is when it is ignited because it is affected by the water content in the oil. The higher the pyrolysis temperature, the less water content in the oil so that the flame quickly grabs and the flash point obtained is getting smaller [9]. The flash point of the liquid product obtained is in the range of 31-36 ° C which is approaching the flash point range of kerosene, which is 38-72 ° C. From Figure 7 it can be seen that the higher the temperature, the lower the flash point of the liquid product.

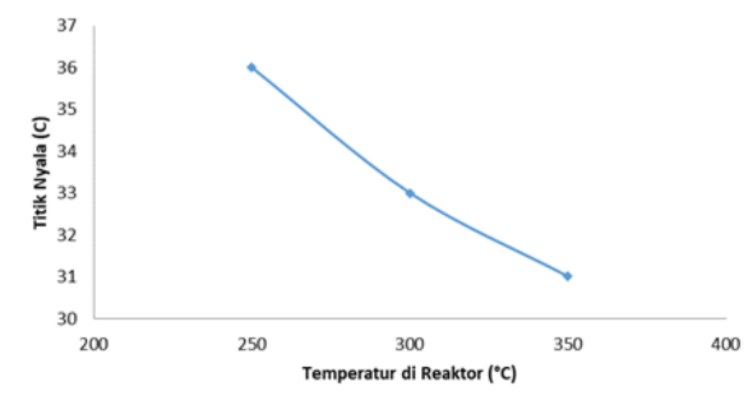

Figure 7. Effect of Temperature Variations on Flash Points

4. Conclusions

The heating temperature in the reactor is one of the variables that influencing the waste plastic pyrolysis process. The higher the operating temperature, the higher the % yield and the volume of liquid product produced. The higher the heating temperature in the reactor, the higher the density and specific gravity. On the other side, the higher the temperature, the lower the Gravity API, Calorific Value, and Flash Point. The flash point of the liquid product obtained is in the range of 31-36 ° C which is approaching the flash point range of kerosene, which is 38-72 ° C.

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