

Pyrolysis of Polypropylene (PP) Into Liquid Fuel Using CaO Catalyst

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Abstract

Pyrolysis has been performed on Polypropylene thermoplastic compounds to produce liquid fuel using CaO catalyst. The pyrolysis process takes place at a temperature of 480 °C with variations in the weight of the catalyst CaO 0; 2.5; 5; 10 g. The highest oil quantity was obtained by adding 5 g of catalyst by 49.5% with the percentage of gas and coke was 50.33% and 0.66%, respectively. in general, the results of GC-MS analysis show the content of liquid fuels in the form of hydrocarbons with carbon content in the C₄-C₁₂ and C₁₃-C₂₄ ranges which is predicted as fractions of gasoline and diesel.

Keywords: *Pyrolysis, Polypropylene, Catalyst, CaO*

1. Background

Increasing energy consumption and increasing landfill are two problems that arise along with economic growth and population growth. The disposal of waste plastics is a serious environmental problem. The increase in the amount of plastic waste threatens the stability of the environmental ecosystem, because plastic is a non-biodegradable material (plastic which cannot be biodegradable). Some synthetic plastic products such as polyethylene terephthalate (PET), high density polyethylene (HDPE), polyvinyl chloride (PVC), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), polyurethane and polyphenols, produce plastic waste that is approximately 50-60% of PE, 20-30% of PP, 10-20% PS and, 10% PVC (Sarker, 2013).

One type of plastic that is very widely used by the public is Polypropylene (PP). Polypropylene (PP), also known as *polypropene*, is a thermoplastic polymer used in a wide variety of applications. It is produced via chain-growth polymerization from the monomer propylene. Polypropylene is second-most widely produced commodity plastic (after polyethylene) and it is often used in packaging and labeling.

Although the recycling of waste plastics is considered appropriate for the resource circulation society, many of them are still landfilled or incinerated, because the material recycling of many plastics is still difficult due to the large content of other impurities, such as pigments, paper, and alumina, in the waste plastics. The landfill and incineration of waste plastics is undesirable, owing to its non-biodegradability and harmful gas emissions (Lee, 2006).

Various solutions have been made to overcome the problem of plastic waste. One of them is by processing polyethylene plastic types into liquid fuels as one of the renewable energy breakthroughs by pyrolysis method. This is based on research from Syamsiro (2015) which states that plastic is one of the derivative products from petroleum. Therefore, plastic has a high energy content such as fuel in general such as gasoline, diesel and kerosene. Various

types of plastics such as polyethylene (PE), polypropylene (PP) and polystyrene (PS) have calorific values equivalent to fuels derived from petroleum such as kerosene, diesel and heavy oil.

Research on pyrolysis of various types of plastics has been widely carried out, but the resulting liquid fuel still has shortcomings, so we need another alternative to obtain liquid fuels that are suitable for use, one of which is by adding CaO as a catalyst during the pyrolysis process. Benefits of using a catalyst is that it can reduce the reaction temperature, this is what causes the process that uses catalysts to do more to improve product quality.

Bermis (2012), shows the level of catalyst quality in the pyrolysis process. His research results show that SiO₂ catalysts produce liquid fuel products which are better than pyrolysis without catalysts, where the conversion of liquid fuels is above 70%. Therefore, this research will carry out the process of pyrolysis of polypropylene into a liquid fuel using CaO catalyst.

2. Methods

Sample Preparation

Preparation of polypropylene bottle (PP) begins with the washing process. Waste of polypropylene (PP) plastic bottles is washed with soap and rinsed with distilled water. Bottles that have been washed are then cut to size 3 mm × 3 mm to 4 mm × 4 mm. The next step is the cut-out plastic is washed again with distilled water and dried in the oven for one hour.

Pyrolysis of Polypropylene

Enter the ingredients in the reactor with the composition of polypropylene (PP) plastic with CaO (powder) catalyst mixed. Pyrolysis at a temperature of 480°C with a variable ratio of plastic polypropylene (PP): CaO catalyst (200 g: 0 g, 200 g: 2.5 g, 200 g: 5 g, 200 g: 10 g) and record the time obtained and the temperature when Polypropylene (PP) plastic pyrolysis takes place. Steam from PP plastic decomposition will be flowed through vertical cooling to the reservoir (Erlenmeyer 250 mL). After no more droplets of polypropylene (PP) plastic liquid, the container (Erlenmeyer 250mL) is closed tightly so as not to evaporate. If the pyrolysis process is complete, the stove is turned off. Weigh the product obtained, then cool the reactor then weigh the residue. The procedure is repeated with the other heavy variables of the catalyst (Salamah, 2016).

GC-MS Characterization of Liquid Fuels

The resulting oil is put into a beaker glass and added anhydrous Na₂SO₄ until saturated, then the beaker glass is closed tightly and allowed to stand for 24 hours, after 24 hours the filtration process is carried out. Furthermore, the oil in the upper layer is separated from the lower layer using a separating funnel, then the oil in the upper layer is taken using 10 mL spout to be analyzed by GC-MS.

This test was conducted to determine the percentage of compounds contained in pyrolysis oil. Based on the results of GCMS testing, it can be known the name of the compound and the form of the compound indicated by number of peaks (peak). After that, identify the compound according to the main group group so that the type of oil can be determined based on the compound contained.

Data Analysis

Calculating the quantity and density is done to determine the density of the oil produced by pyrolysis obtained by the equation as follows:

Gas mass	= Biomass mass - (Bio-oil mass + Charcoal mass)
Bio Oil Quantity	= (Bio-oil Mass / Biomass Mass) x 100%
Charcoal Quantity	= (Charcoal Mass / Biomass Mass) x 100%
Gas Quantity	= (Gas Mass / Biomass Mass) x 100%
Bio Oil Density	= Massa / Volume

3. Results and Discussion

Effect of catalyst weight on oil, charcoal and gas quantities

Yuliansyah *et al* (2015) said that the factors that can affect the quantity of liquid fuel include the type of pyrolysis raw material, the percentage of raw materials, particle size of raw materials and heating temperatures.

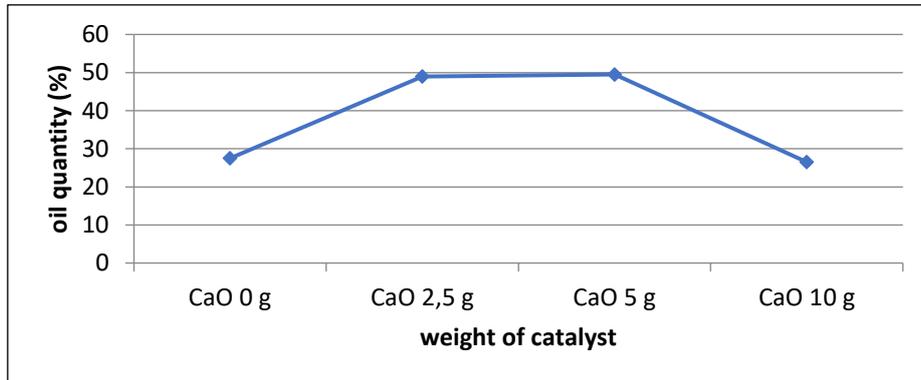


Figure 1. Comparison of the quantity of oil products

Figure 1 shows that the largest oil product is in a 5 g CaO mixture, which is 49.5% and is slightly higher than the 2.5 g CaO mixture. According to Danarto (2010), this is because the catalyst increases the decomposition reaction which results in more and more long chain hydrocarbons being split into short chain hydrocarbons so that more gas is formed which is then condensed into a liquid resulting from pyrolysis. In the mixture of CaO 0 g the oil product obtained was 27.5% and the lowest oil product was obtained from the 10 g CaO mixture that is equal to 26.5%. The decline in oil products occurs in a mixture of 10 g CaO, this is due to the pyrolysis with a catalyst of 10 g CaO has passed the optimum point of the process of polypropylene plastic pyrolysis (PP) (Salamah, 2016).

In a mixture of CaO 10 g the fuel obtained is frozen at room temperature so the fuel must be diluted through the heating process before being used as fuel. This is because at the time of pyrolysis takes place there are still many molecules in large sizes that made it through the condenser. However, a 10 g CaO mixture can produce a stable flame just like any other CaO mixture.

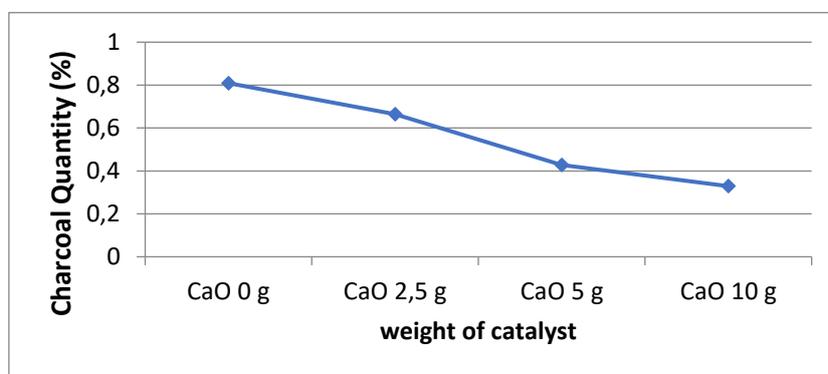


Figure 2 Weight of catalyst vs quantity of charcoal product

The percentage of charcoal can be seen in Figure 2, where the highest percentage of charcoal obtained in the mixture of 0 g of CaO of 0.809% then continued to decrease with almost the same percentage value ie each of the 2.5 g of CaO mixture of 0.665%, CaO mixture 5 g of 0.428% and a mixture of CaO 10 g of 0.329%. The curve also shows that the presence of a catalyst causes a decrease in the quantity of charcoal produced as the weight of the catalyst increases. however, the addition of 10 g of CaO showed a discrepancy with the

previous results, where the quantity of oil was lower than the addition of 2.5 g and 5 g CaO, even though the quantity of charcoal produced was less. this is caused by the gas produced not being condensed completely into a liquid because the pyrolysis device used still has a gap where oxygen can enter the reactor, so the quantity of oil produced is low (Thahir *et al*, 2019)

Figure 3 shows the relationship curve between the weight of the catalyst and the quantity of gas in each sample. on the curve clearly shows the low quantity of gas in the mixed sample of 2.5 and 5 g CaO compared to the sample without the CaO catalyst. this indicates that during the pyrolysis process the gas was mostly condensed into a liquid, as evidenced by the high quantity of oil in both samples as shown in the Figure 1.

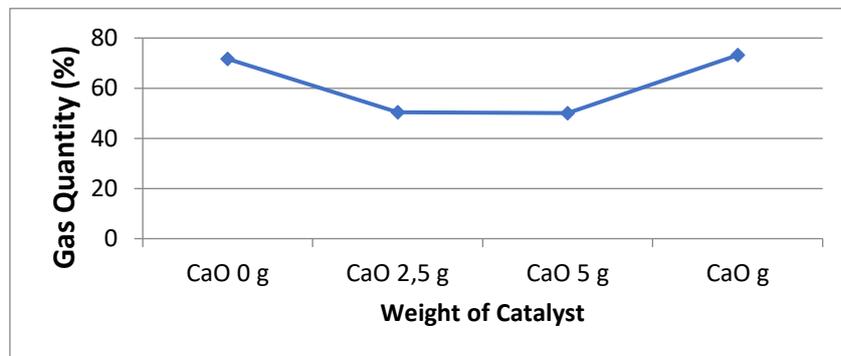


Figure 3. The relationship of catalyst weight to the quantity of pyrolysis product gas

GC-MS Analysis

Based on the results of the GCMS test, it was found that the groups forming the compounds in liquid fuels in a mixture of 0 g, 2.5 g, 5 g and 10 g CaO were dominated by hydrocarbon compounds. This is due to pyrolysis using plastic raw materials derived from fossil fuels or petroleum so that it contains many hydrocarbon compounds. Figure 3.4 shows the GC-MS chromatogram of the pyrolysis oil fraction. Chromatogram interpretation results show that the four liquid fuel samples contain hydrocarbons with carbon content in the range C4 to C18 with a level of similarity or quality above 60%. Liquid fuel samples with the addition of 2.5 g catalyst containing the highest amount of hydrocarbon compounds which have carbon content in the C4-C17 range which are alkanes, esters, and succinic anhydride compounds, with similarity level between 72-94 % (more details can be seen in the table 3.1), whereas in samples with the addition of 0 g, 5 g, and 10 g CaO, the predicted number of compounds with a similarity level above 60% is only 2-3 compounds, including dodecane and heptane derivatives. This is in accordance with the previous results, where the percent of oil produced in the pyrolysis sample with the addition of 2.5 g CaO is higher than the other samples, especially for samples without the addition of CaO catalyst.

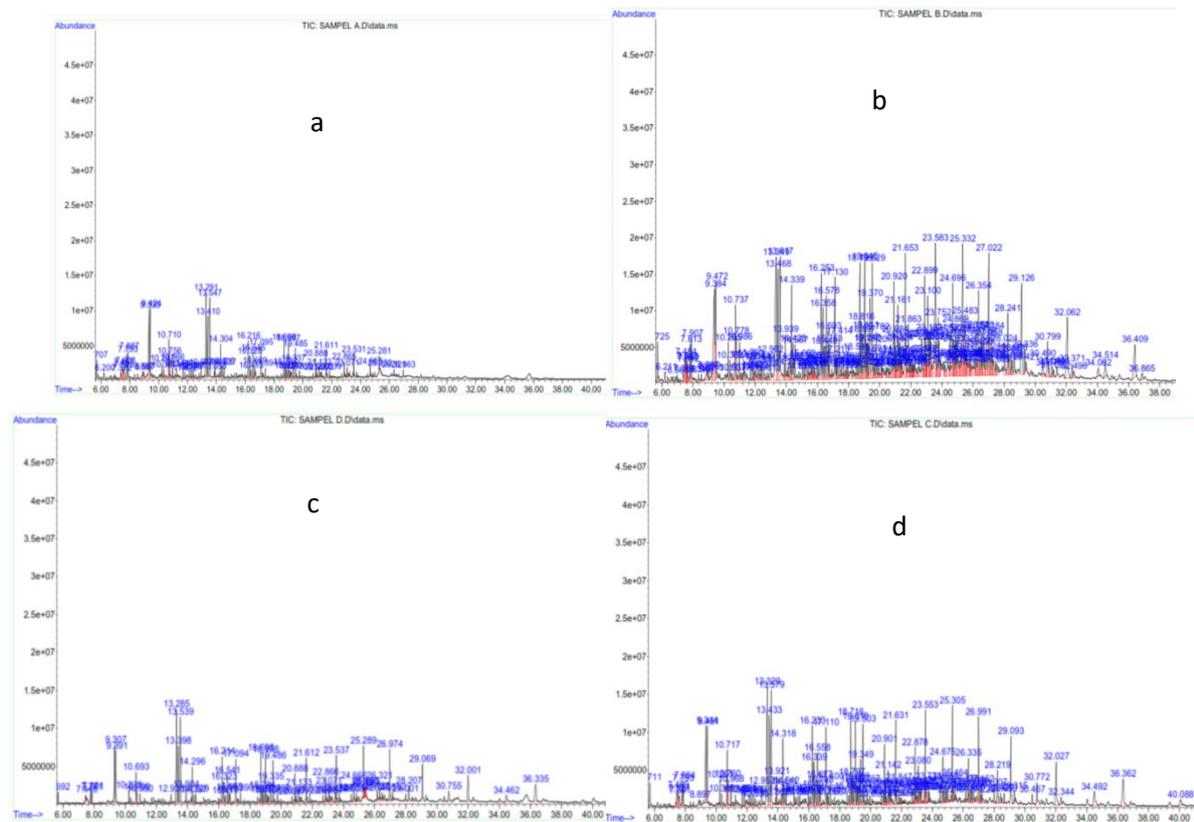


Figure 4. Chromatogram of pyrolysis product (a) 0 g CaO, (b) 2.5 g CaO, (c) 5 g CaO, (d) 10 g CaO.

Table 1. GC-MS analysis results on liquid fuel samples

Liquid Fuel	% area	Compound prediction	Quality (%)	Molecule formula
LF CaO 0 g	0,53	4,6 Dimethyldodecane	93	C ₁₄ H ₃₀
	0,53	7 - methyl -heptadecane	72	C ₁₈ H ₃₈
	2,10	n-Nonenyl succinic anhydride	72	C ₄ H ₄ O ₃
LF CaO 2,5 g	0,08	Cyclohexane, 1,1-dimethyl-2 propyl	93	C ₁₁ H ₂₂
	0,08	1-ethyl-2,2,6-trimethylcyclohexane	91	C ₁₁ H ₂₂
	0,11	2-Undecene, 8-methyl	94	C ₁₂ H ₂₄
	0,24	2,4-Diethyl-1-methylcyclohexane	78	C ₁₁ H ₂₂
	0,18	4,6-Dimethyldodecane	81	C ₁₄ H ₃₀
	0,18	3,4-Dimethyldecane	72	C ₁₂ H ₂₆
	0,14	Sulfurous acid, 2-propyl tetradecyl ester	72	C ₁₇ H ₃₆
LF CaO 5 g	1,48	n-Nonenyl succinic anhydride	87	C ₄ H ₄ O ₃
	0,19	4,6 Dimethyldodecane	93	C ₁₄ H ₃₀
LF CaO 10 g	0,19	7- methyl -heptadecane	72	C ₁₈ H ₃₈
	0,57	Bicyclo [2.2.1] heptane-2,5 dione	72	C ₇ H ₈ O ₂
	0,60	6-Tridecene, 7-methyl	68	C ₁₄ H ₂₈

Based on the amount of carbon elements in liquid fuels, it can be concluded that the mixture of CaO 0 g, 5 g, and 10 g is a diesel or diesel type fuel because it has compounds with carbon elements in the range C13-C24, whereas in CaO 2 mixture 5 g has a compound contained in gasoline (range C4-C12), in addition, there are also some compounds contained in diesel or diesel (range C13-C24).

4. Conclusion

The addition of CaO catalyst in the polypropylene pyrolysis process greatly affects the amount of liquid fuel fraction. addition of 2.5 and 5 g CaO catalysts produced the highest oil fractions of 50.33 & and 50.07%. Liquid fuel samples contain hydrocarbons with carbon content in the C4-C18 range which are compounds in the gasoline and diesel fractions.

5. Citation and References

- Bemis, R., Novesar, J., Syukri, A. (2012). *Processing Polypropylene Waste into Liquid Fuels through the Pyrolysis Method*. Material Laboratory of Andalas University. Vol. 5, No. 2.
- Danarto, Y.C., Prasetyo Budi Utomo., Ferry Sasmita. (2010). *Pyrolysis of Wood Powder Waste with Zeolite Catalysts*. Prosiding of National Seminar Chemical Enggenering:Yogyakarta.
- Lee, K.H., (2006). *Thermal and catalytic degradation of waste HDPE*. In: Wiley, John (Ed.), *Feeds Stock Recycling and Pyrolysis of Waste Plastics*. John Wiley & Sons, Ltd, Canada, <http://dx.doi.org/10.1002/0470021543.ch5>.
- Salamah, S.,and Maryudi. (2016). *Pyrolysis of Sterofoam Waste with Ni / Silica Catalysts*. National Symposium on Applied Technology, Ahmad Dahlan University.
- Sarker, M., dan Rashid, M. M. (2013). *Food Container Waste Plastic Conversion Into Fuel*. International Journal of Engineering and Applied Sciences. Vol. 3 No. 1.
- Syamsiro, M. (2015). *Study of the Effect of Use of Catalysts on the Quality of Oil Products from Plastic Waste Pyrolysis*. Journal of Engineering, Janabadra University. Vol. 5 No. 1.
- Thahir, R., Altway, A., Juliastuti, S. R., Susianto. (2019). *Production of liquid fuel from plastic waste using integrated pyrolysis method with refinery distillation bubble cap plate column*. Energy Reports (5), 70–77.
- Yuliansyah, T.A., Agus, P., Ramadhan, A.A.M., Laksono, R., (2015). *Pyrolysis of plastic waste to produce pyrolytic oil as an alternative fuel*. Int. J. Technol. 7, 1076 – 1083.