produced the best characteristics was a variation of 60 minutes time of cracking process and 4% of the catalyst. From that result, then this variation was further used to be varied by the operating temperature, which was 150, 200, 300 and 350oC. The characteristics of the product from the process using a different range of temperature can be seen in table 4.

TABLE IVV
CHEMICAL PROPERTIES OF PRODUCT USING DIFFERENT RANGES OF TEMPERATURE

Length of Cracking Time (minute)	Operating Temperature (°C)	% Catalyst	Analyzed Parameters		
			Density (gr/mL)	Spgr	°API Gravity
60	150	4	0.747	0.762	54.2
60	200		0.747	0.762	54.2
60	300		0.758	0.773	51.5
60	350		0.762	0.778	50.4

B. *Conversion and Yield Percentage of Product*

From the product's mass data, the conversion and yield percentage can be calculated. The calculation result can be seen in table 5 below.

TABLE V
PERCENTAGE OF CONVERSION AND YIELD OF PRODUCTS

% Catalyst	Operating Temp (°C)	Length of Cracking Time (minute)	% Conv.	% Yield		
				Liquid	Solid	Gas
-	250	20	72.9	5.7	27.1	67.1
		40	73.9	6.2	26.0	67.7
		60	75.5	6.8	24.5	68.7
4	250	20	78.0	10.3	21.9	67.7
6			75.9	8.6	24.0	67.3
8			73.7	6.5	26.3	67.2
4	250	40	79.9	13.2	20.0	66.7
6			77.9	10.3	22.1	67.6
8			74.8	7.3	25.2	67.5
4	250	60	81.2	14.6	18.8	66.6
6			79.3	11.9	20.7	67.5
8			74.9	7.7	25.1	67.1
4	150	60	78.5	10.9	21.5	67.6
4	200		79.6	13.1	20.4	66.5
4	300		81.4	14.8	15.8	66.7
4	350		84.2	17.5	18.6	66.8

From the data above, it can be seen that for operating temperature of 250oC without a catalyst, the highest conversion was at 60 minutes time of cracking process, as much as 75.5%. As for the other variation using the same operating temperature of 250oC with different percentage of catalyst, it can be concluded that the conversion percentage of products were rising as long as the length of the cracking time, so in this case, 60 minutes were the best time of cracking process. For a variation of 4% catalyst, the conversion percentage reached the highest value of 81.2%, while when using 6% catalyst, the product's conversion reached 79.3% of value and the last variation of 8% catalyst got the highest conversion of 74.9% of value. The experiments using different ranges of temperature obtained the highest value of product's conversion as much as 84.2% at a temperature of 350oC. So was the yield percentage of the liquid product. The primary focus of this research was to obtain a liquid product that can be used as gasoline's substitute, so it was important to narrow the discussion around the liquid product but without ignoring the other products (gas) and residue (solid) because all of them were related. The highest yield of liquid for without catalyst process was 6.8%, and for 4% catalyst, it was obtained as much as 14.6% of the liquid product. As for variations of 6% and 8% of catalyst decreased respectively, as much as 11.9% and 7.7%. At the range temperature of 350oC, using 4% catalyst for 60 minutes, it reached the highest value of 17.5%.

C. *The Effect of Length of Cracking Time and Percentage of Catalyst Towards Conversion Percentage of Products*

The effect of the length of cracking time and percentage of catalyst towards the conversion percentage of products can be seen in the chart below.

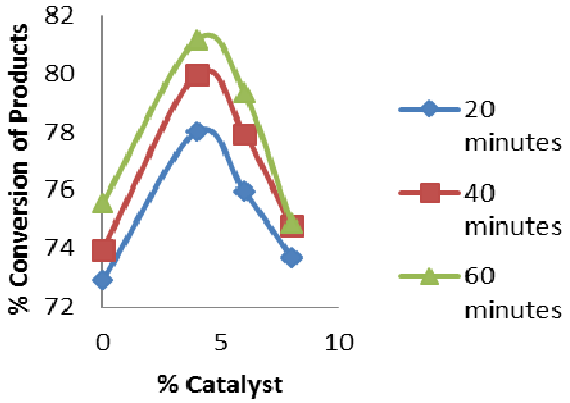

Fig. 2 Effect of The Length of Cracking Time and % Catalyst Towards % Conversion of Product

From Fig. 2, it can be seen that the effect of cracking time towards conversion percentage of products was increasing the value of the conversion. If the time of cracking process was longer, then the conversion percentage was higher also. Reference [9] stated that the longer the reactant was reacted, the product that was produced was higher also, that was because the reactant would be cracked entirely along with the increasing of time. So, 60 minutes was the best time for cracking process of polypropylene, because the longer the process was going, the more significant part of the raw material that was converted into product. While for the effect of catalyst, it can be seen that cracking process without catalyst had the lowest value of the conversion. It was because cracking process without catalyst presence was called as thermal cracking (thermal pyrolysis) and the thermal pyrolysis requires high temperatures, which often results in products with low quality.

This method can be improved by the addition of catalysts, which will reduce the temperature and reaction time and allow the production of hydrocarbons with a higher added value. On the other hand, the catalyzed pyrolysis promotes these decomposition reactions at lower temperatures and shorter times, because of the presence of catalysts that assist

in the process. Thus, the catalytic pyrolysis presents some advantages over thermal, such as lower energy consumption and product formation with a narrower distribution of the number of carbon atoms, which may be directed to aromatic hydrocarbons with light and high market value [10].

It was proved in this experiment, where the product's conversion was higher in the presence of a catalyst, compared to the one which used no catalyst. However, it also can be seen that 4% catalyst variation reached the highest conversion of product. Theoretically, the catalyst can enhance the cracking reaction of the pyrolysis gas, but when the amount of catalyst was too much, the presence of catalyst could reduce the liquid fraction and increased the gaseous fraction [11], while the purpose of this research was to obtain a liquid fuel. An experiment using Polypropylene with Activated Carbon catalyst also revealed that using too much catalyst could make the product distribution almost like a process without using catalyst, especially on a higher temperature [12],. That is why, in the chart, it can be seen that product conversion from cracking process using 6 and 8% of catalyst kept decreasing. So the maximum percentage of Al2O3 for the catalytic cracking process using Polypropylene as a raw material was 4%.

Furthermore, the effect of cracking time and percentage of catalyst towards the yield percentage of liquid product showed the same pattern with the conversion percentage of product, because surely they were all related, where the higher liquid product was produced, the conversion percentage will be higher also. The effect of cracking time and catalyst percentage towards liquid product's yield percentage can be seen in figure 3.

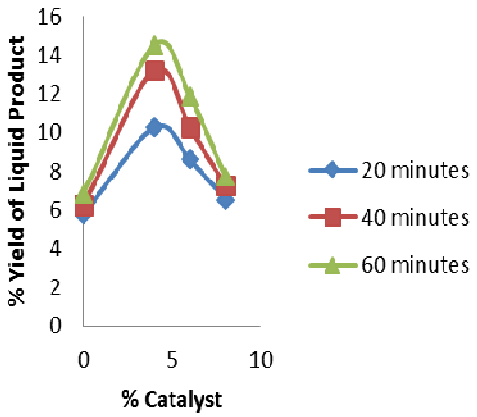

Fig. 3 Effect of The Length of Cracking Time and % Catalyst Towards % Yield of Liquid Product

From Fig. 3, it can be seen that yield of liquid product kept increasing along with the increasing of time, showed that the increase of time had a linear relationship towards the liquid product's yield caused by the more prominent part of the raw material that was cracked. As for the effect of catalyst, Anggoro (2008) in Reference [9] stated that the higher the catalyst percentage was, the yield of proda cut will be higher also, but in an absolute limit, it will decrease eventually. This was because not all the pores in the catalyst were used to decompose plastic's molecules into a simpler compound. Thus, in this experiment, the best selection for the time of cracking process and percentage of the catalyst using Polypropylene as raw material and Al2O3 catalyst was 60 minutes of the process using 4% of catalyst addition.

D. Effect of Temperature Towards Conversion and Yield Percentage of Products

There were some reasons for selecting the temperature of 250oC for the first nine trials of this cracking process experiment. Pyrolysis, cracking or devolatilization was a material fractionation process by temperature [13]. Pyrolysis process was started at around 230oC of temperature when the components were stabilized thermally, and volatile matters of the plastic waste will be broken down and vaporize together with the other components. For Polypropylene, Reference [14] researched thermal cracking using Polypropylene (without the presence of a catalyst), and the process' temperature was 500oC. While Reference [12] started the experiment at a temperature of 200oC, then varied into 250oC where the results showed an increasing value of the liquid product, also using Polypropylene as the raw material and activated carbon as a catalyst, which the presence of catalyst tend to lower the temperature of the process. That is why the temperature of 250oC was selected as a fixed variable because it was slightly more than the initially started temperature of pyrolysis process and temperature where the yield of the product started to increase in Reference [12] experiment. It can be seen that how much product that can be produced in temperature of 250oC with other moving variable such as time of cracking and percentage of the catalyst.

After using 250oC as fixed variables with other moving variables obtained the best product, it was again varied by the temperature, because in some researches, it was said that for Polypropylene, the temperature at more than 250oC could increase the yield of liquid product. However, in this experiment, two lower temperature than 250oC was also used, to see their effect on the production of liquid fuel. So the experiment was held using variant temperature of 150, 200, 300 and 350oC, with fixed variable of 60 minutes cracking time and 4% of the catalyst. The effect of temperature towards conversion and yield of liquid product percentage was shown in Fig. 4 and Fig. 5.

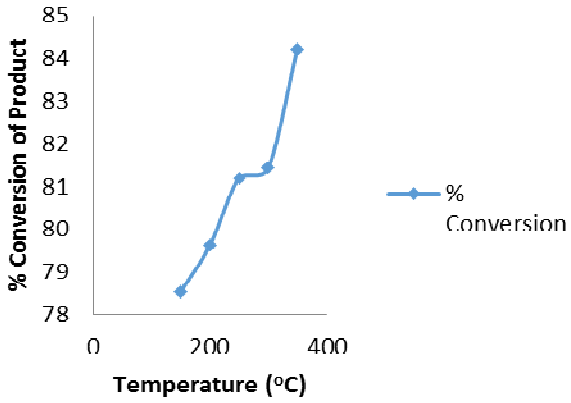

Fig. 4 Effect of Various Temperature Towards % Conversion of Products

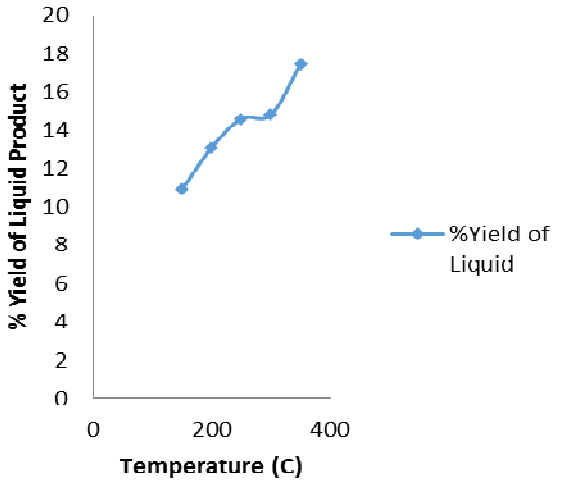

Fig. 5 Effect of Various Temperature Towards % Yield of Liquid Products

Fig. 4 and Fig. 5 showed that those two charts had the same trend, where the higher the temperature of the process was, the conversion and yield percentage of the product were higher also. It also can be seen that at a temperature of 350oC, the conversion and yield of the liquid product had not seemed to decrease, which showed that 350oC was not the temperature limit of the process. Discussing the limit of the process' temperature, some researches showed different trends.

Reference [15] who was using Polypropylene with Ni-Mo/ZA catalyst varied the temperature of the process into 350, 400 and 450oC, and the results showed that at a temperature of 400oC, the yield of product was increased and then decreased at a temperature of 450oC. Setiadi and Fitria (2006) in Wulandari (2015), stated that temperature had an essential effect towards the reaction rate of cracking process. Thermodynamically, the chemical balance will be achieved faster at high temperature, while in kinetics, the reaction rate will increase along with the increasing of temperature. However, when the reaction temperature was increased beyond its optimum temperature, the decreasing of product's conversion percentage will occur (liquid product), and the gas production will increase.

In the other hand, Reference [3] did a research using Polypropylene and NiO/ɣ-Al2O3 with temperature variation of 400, 450 and 500oC concluded that the highest yield of product was obtained at temperature of 500oC, but Reference [16], using PETE as raw material and pure Al2O3 catalyst showed that the range of temperature of 200-400oC with maximum yield of product was reached at temperature of 400oC. The process' temperature of cracking process using Polypropylene and Al2O3 catalyst can be higher than 350oC, but it can not be done in this research due to the compatibility of the equipment (catalytic cracking unit). However, still, using 350oC as temperature obtained a respectively good conversion and yield of product, which also the best among all of the variations in this research.

A. Product's Composition of Polypropylene's Catalytic Cracking Process

The composition of the product was related to the quality of the product itself. The primary purpose of this research was to obtain a liquid product that had similar characteristics with gasoline. The determination of this composition was done by using the GC-MS instrument. The liquid product has been classified into three groups i.e, the gasoline fraction ($C_5 - C_{12}$), diesel fuel fraction ($C_{13} - C_{20}$) and heavy oil ($>C_{20}$). From 2 samples, one sample was product that had the highest liquid yield and the best characteristics, which was from catalytic cracking process with variation of 60 minutes of cracking time, 350^{o}C of temperature and 4% catalyst addition, while the second sample was product that had the lowest liquid yield with lower quality of characteristics. The result of the best liquid product's GC-MS analysis could be seen in Fig. 6, while the other can be seen in Fig. 7.

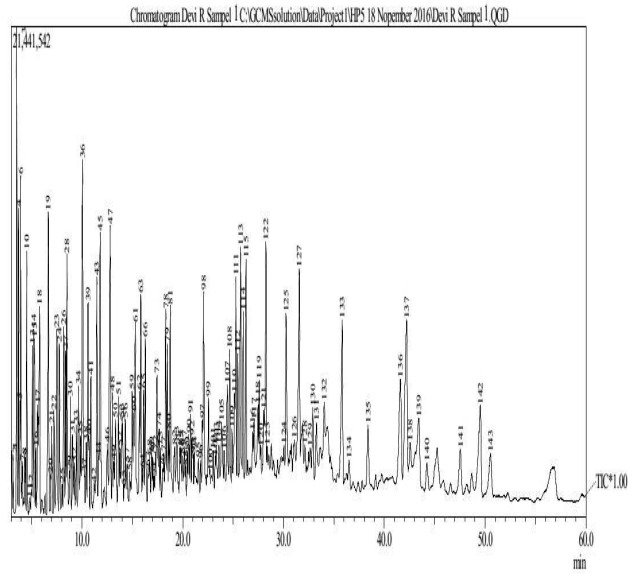

Fig. 6 GC-MS Analysis of Liquid Product with Variation of 350^{o}C, 4% of Catalyst and 60 minutes of Cracking Time

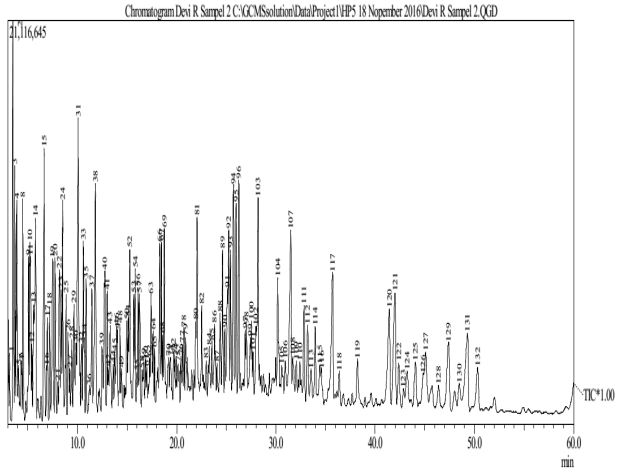

Fig. 7 GC-MS Analysis of Liquid Product with Variation of 250^{o}C, 8% of Catalyst and 20 minutes of Cracking Time

The composition of the liquid product consists of alkane, alkene, toluene, naphthalene and other compounds. This liquid product was selected to be the best among all of the products because it had the highest percentage of gasoline's

range (C5-C12) and only slightest amount of other compounds, and also a little amount of diesel range (C13-C20). This is due to high temperature that was used in the process, which optimized the cracking process of the raw material, resulting in the high products of gasoline.

IV. CONCLUSIONS

Polypropylene plastic wastes conversion to liquid fuel oil by a catalytic cracking process using Al2O3 catalyst experiment is intended to find the optimum condition for producing a liquid product which has similar characteristics to gasoline. There are some factors to be considered to achieve that goal; among them are the length of cracking time, catalyst addition and optimum operating condition.

From the experiment conducted, it can be concluded that: The variation of cracking time, catalyst percentage and operating temperature influence the yield of a liquid product as the primary purpose of research. The optimum conditions for catalytic cracking of polypropylene with Al_2O_3 catalyst are at 60 minutes of the process, the temperature of 350^oC with 4% catalyst addition, which produced 17,5% yield of liquid product. The highest percent composition of gasoline range (C_5-C_{12}) was 80.93% respectively at a temperature of 350^oC

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